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RICHARDSON, GRAHAM
SPATIAL THOUGHT AND VERBAL ABILITY IN
CHILDREN RETARDED IN READING.

UNIVERSITY OF CAMBRIDGE (GREAT BRITAIN),
PH.D., 1980

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SPATIAL THOUGHT AND VERBAL ABILITY IN CHILDREN RETARDED
IN READING.

Graham Richardson

Submitted for the Degree of Doctor of Philosophy in the University
of Cambridge.

Clare Hall,
Cambridge.

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PREFACE

This study was begun at Imperial College of Science and Technology, University of London, under the supervision of Professor Colin Cherry, and with the support of a postgraduate research studentship from the Science Research Council (from October 1969 to September 1971). The work carried out there was concerned with developing a theoretical model to account for various phenomena which are said to be characteristic of children with specific reading retardation. A paper describing this analysis is submitted as an Annex to this dissertation. The experimental phase of the study, the main aim of which was to verify certain aspects of the theoretical model, was carried out in the Medical Psychology Unit, Department of Experimental Psychology, University of Cambridge, under the supervision of Professor O.L. Zangwill, and was supported by grants from the Nuffield Foundation (from January 1973 to September 1975), the Kenneth Craik Fund, St. John's College, Cambridge (awarded December 1975), the H.E. Durham Fund, King's College, Cambridge (awarded May 1976), and the Social Science Research Council (from December 1976 to November 1977). The support of these bodies is gratefully acknowledged.

I would like to express my gratitude to a number of people for their assistance and advice in the planning and execution of this project. Mr. I.G. Cunningham, formerly Chief Education Officer, Cambridgeshire County Council, and Mr. D. Spreadbury, Senior Area Education Officer, granted permission for the study to be conducted in Cambridgeshire schools. In the planning stage, the project was discussed with Dr. May Brenner, Educational Psychologist, who advised

on a number of administrative and practical issues connected with the work in schools. Mr. Sydney Wrench, Senior Advisory Remedial Teacher, gave invaluable advice on procedures for the educational screening of children, and was also instrumental in selecting the schools that took part, in gaining their cooperation, and effecting introductions to the headteachers. Mr. Derek Last, County Adviser for Resources, allowed me the use of a room, for the purpose of testing children, at the Resource and Technology Centre, Ely, Cambs., during the summer holidays of 1975 and 1976. Mr. Asbridge, headteacher of Romsey Junior School, arranged for me to contact parents in order to seek permission to use their children's school photographs as part of the test materials. Mrs. V. Wight-Boycott, formerly Secretary of the Cambridge Dyslexia Association, approached several members of the Association to enquire whether they would be willing for their children to participate in the pilot testing of materials and procedures to be used in the study proper. I am grateful to the parents and children who cooperated at this stage. Mrs. Wendy Fisher, Executive Director of the Dyslexia Institute, Staines, Middx., gave me permission to examine the records of children who had undergone educational and psychological assessment at the Institute.

Thanks are also due to the headteachers and staff of the following schools for their generous cooperation in providing facilities for the tests to be conducted and for their efforts in support of the project:

Cottenham Primary School,
Cottenham, Cambs.

Fulbourn Junior School,
Fulbourn, Cambs.

The Grove Junior School,
Cambridge.

John Paxton Primary School,
Sawston, Cambs.

King's School,
Ely, Cambs.

Linton Junior School,
Linton, Cambs.

Histon Junior School,
Histon, Cambs.

Mayfield Primary School,
Cambridge.

Meridian Primary School,
Comberton, Cambs.

The Village College,
Comberton, Cambs.

St. Andrew's Junior School,
Chesterton, Cambs.

The Village College,
Sawston, Cambs.

St. Mary's Junior School,
Ely, Cambs.

Waterbeach Primary School,
Waterbeach, Cambs.

Thames Ditton Junior School,
Thames Ditton, Surrey.

Waynelete County Secondary School,
Esher, Surrey.

I am greatly indebted to the parents who gave permission for their children's participation, and who provided extensive information on their backgrounds, and to the children themselves for their willingness in undertaking the lengthy program of tests, extending as it did, in most cases, over a period of 12-18 months.

I would like to thank my supervisor, Professor O.L. Zangwill, for providing the opportunity to continue the work begun at Imperial College and for his unfailing support, encouragement, and advice. I am also grateful to Dr. Martin Richards for the use of facilities in the Medical Psychology Unit throughout the course of the project.

This work could not have been completed without the support in many forms, both tangible and intangible, of my wife, Margaret Richardson, and my mother, and their help and understanding are gratefully acknowledged.

This dissertation is the result of my own work and includes nothing which is the result of work done in collaboration.

Chapter 1

1.1 Introduction

The process which enables judgments to be made about an object's egocentric orientation is presumed to rest on a frame of reference intrinsic to the visual system. It is shown, by means of an analysis which owes some of its assumptions to work in the field of perceptual adaptation, that the formation of the frame is dependent on certain features of the organism and its environment, and their spatial inter-relationship. Additional experimental evidence is adduced in an attempt to identify the stages in the child's perceptual development at which the projective and euclidean components of the frame emerge.

The model of orientation perception is first applied to an analysis of letter orientation errors, which are a transient feature of many children's reading and spelling in the early stages of learning, but which persist to a later age than normal in some retarded readers. The inference that such errors may occur through the failure of the frame of reference to develop in the usual way is examined, and consideration is given to possible inadequacies in this explanation. The concept of the frame of reference is then used to extend the analysis to two further areas of development in which retarded readers are said to exhibit anomalous performance, the recognition of mono-oriented forms under spatial transformation, and the acquisition of conventionally-ordered series and adjective-antonym pairs.

1.2 The discrimination and identification of figure orientation

The occurrence of letter orientation errors in the reading and spelling of intelligent children who fail to master these skills in the normal way receives widespread mention, and errors of this kind have virtually achieved the status of a sine qua non for the identification of the handicap. Mach (1959) was probably the first to consider how children learn to distinguish letters such as b and d, and a number of other theories concerning the perception of figure orientation have since been put forward, but none has proved to be capable of providing a satisfactory explanation of letter reversals and inversions.

An evaluation (Richardson, 1974) of most of the theories proposed so far suggested that a common flaw in their arguments lay in the failure to recognize that the orientation of an object or a figure is not an intrinsic attribute, but rather a spatially defined relationship existing between the object and its context, or between the object and the perceiver. The determination of this relationship presupposes that a perceptual frame of reference is provided either by virtue of the object's context or through the intrinsic mode of functioning of the perceptual system. This much was recognized by the Gestalt psychologists Koffka (1935) and Kohler (1940), while Fellows (1968) and Gibson and Robinson (1935) were also aware of the underlying principle, though they did not speculate about the nature or origin of the frame of reference. With regard to the latter issue, the work of Piaget and Inhelder (1956), Rock (1966), and Bryant (1974) has led to crucial insights.

Piaget and Inhelder (1956) believe there is a sharp distinction to be drawn between the perceptual system of reference, which is limited in its application to what is present in the here and now, and the representational system of reference which is capable of reconstructing in imagination the past or future organization of spatial elements. Moreover, and in this respect their view is opposed to the one which will be presented here, spatial concepts are not considered to be derived by a process of abstraction from the corresponding perceptual data, but are the product of internalized actions, the role of the image being that of a symbol for the action. Spatial relationships which enter into perception and representation have the same form and develop in the same order in each case, that is to say, topological relationships first, followed by projective and euclidean relationships, but they are reconstructed on the representational plane several years after their construction in perception.

Rock's (1966) investigation into the nature of perceptual adaptation sustains certain assumptions concerning the neural representation of perceptual experience which are made later in formulating a theory of orientation perception.

Bryant (1974) demonstrated that the provision of a contextual frame of reference for the young child can facilitate his judgments of orientation and position, and that the difficulty which he experiences in distinguishing between members of so-called mirror-image pairs does not hinge on the mirror-image relationship per se. Aspects of these four authors' work will be considered at greater length in the course of the theoretical discussion.

The hypothesis to be evaluated, which was formulated in an earlier work (Richardson, 1974), may be briefly stated as follows. In order to recognize a plane figure's orientation within a fronto-parallel plane, in the absence of a visual context, the perceptual system must possess an intrinsic two-dimensional frame of reference. The latter concept is derived from analytical geometry and it can take a number of different forms, but for the purposes of this analysis the most appropriate one is the Cartesian frame, which consists of two orthogonal axes (the horizontal and the vertical, or, more generally, x and y) each one being appropriately labelled at opposite ends (up and down, or $+$ and $-$). The four quadrants of the frame are conventionally designated I through IV proceeding in an anti-clockwise direction from the upper-right quadrant. A co-ordinate system of this kind enables a correspondence to be established between a geometric system (i.e. a series of points or lines) and an algebraic system (i.e. a set of number pairs, (x,y)), though in this particular application it will not be necessary to take advantage of the ultimate resolution of the number system.

In order for the visual system to acquire an intrinsic frame of reference it is necessary for three conditions to be satisfied throughout the course of the child's development:

(1) the visual world should be one in which vertically and horizontally oriented elements predominate, and it should contain a significant number of mono-oriented objects which have vertical and/or horizontal asymmetry.

(2) There should be a more or less consistent spatial relationship between the child and his world; this condition is satisfied once the child learns to stand.

(3) In accordance with the argument put forward by Rock (1966), it is assumed that there is a one-to-one correspondence between the relative orientation of objects or figures in the world and the relative orientation of their memory traces in the neural substrate. (This condition would appear to rest on the further assumption that the pattern of neural excitation which is produced by a two-dimensional figure has a form which is homeomorphic with, or topologically equivalent to, the figure itself.)

Rock refers to the characteristic described in (3), above, as the stimulus-copy aspect of a memory trace; it is a feature which is not confined to the parameter of orientation, but is also applied to other properties of the proximal stimulus, such as straight/curve. These absolute attributes of the memory trace serve as signs of phenomenal features which constitute the representational aspect of the trace and are also stored in memory.

Conditions (2) and (3), above, ensure that the traces of figures in the physical world having directional or polar elements in common are oriented in such a way that there is virtual coincidence, in respect of orientation, between the corresponding stimulus-copy aspects. Given the structure of the physical world, in which there is a predominance of vertical and horizontal elements and of figures whose principal axes are similarly oriented, the consequence of exposure to this environment over a long period of time is that the resulting complex of memory traces is endowed with the same structure. This accommodation would not occur if there was a variable spatial relationship between the perceiver and his world (as would be more likely to occur in a zero-g environment) or, even with condition (2) satisfied, if the mode of neural processing was

such that there was a many-to-one correspondence between the relative orientation of objects or figures in the world and the relative orientation of the corresponding memory traces.

It might appear, at first sight, that a theory of orientation perception could be based on conditions (2) and (3) alone, but it is possible to show that they are not sufficient by considering a simple memory system placed in an environment in which the only visual stimuli are the four letters b, d, p, and q. The resulting trace complex is symmetric about both the horizontal and vertical axes, so that it is incapable of serving as a frame of reference for any figure which might subsequently be presented. Although, in accordance with assumption (3) above, a given orientation of the figure results in a unique orientation of its memory trace, it does not follow directly that the perceiver has knowledge of the orientation of the trace relative to his own body. The assumption that he does have this knowledge leads to a solution suggestive of that entailed in a template theory and is clearly inadequate because the question as to how the b-template, for example, comes to be labelled as such is passed over. Nor can it be assumed that the registration of the stimulus-copy aspect of the four letters b, d, p, and q automatically makes available corresponding phenomenal representations which can in turn form the basis for the association with the phonemes or letter names. In fact, it will be shown later that, without a trace complex that is characterized by horizontal and/or vertical asymmetry, changes in the phenomenal form of a figure with changes in orientation cannot take place. Therefore the only kind of successive discrimination that is facilitated by the biaxially symmetric framework resulting from the traces of the four letters b, d, p, and q

is one relating to the verticality or otherwise of the straight feature, a criterion which does not enable them to be differentiated. This simple system could conceivably support same/different judgments regarding simultaneously presented pairs of letters, since one letter could serve as the reference for the other, but it is not legitimate to extend this argument by suggesting that if one of the memory traces served the same purpose then recognition and identification of individually presented letters would also be possible, because this proposal entails the unwarranted assumption that one of the four traces has a special status and that its identity is already given. Thus, if it is correct to assume that the visual frame of reference derives from the accumulated effects of visual experience, it is clear that this experience must include visual contact and interaction with mono-oriented, vertically and horizontally asymmetric, objects. This condition, in conjunction with (2) and (3) above, needs to be satisfied in order for the trace complex to acquire the requisite directional and polar properties.

In the course of the foregoing analysis the form and orientation of a figure were treated as independent properties, but putting the problem in these terms tends to obscure the manner in which the two attributes are perceived phenomenally. For most individuals the ease with which a complex mono-oriented figure, such as a word or a face, is recognized depends on its egocentric orientation, but at the same time a judgment about its orientation can only be made if the form, or at least the class to which it belongs, has been recognized. In other words, while changes in phenomenal form which are associated with changes in a figure's orientation may affect the ease with which it is recognized,

it is just these variations which in all cases enable judgments of a figure's orientation to be made. For example, suppose that a square form is placed on the floor and viewed from directly above, so as to minimize the influence of any contextual framework. If a pair of opposite sides lies in the same direction as the top-bottom axis of the head, then the figure appears phenomenally square. However, if it is rotated 45 degrees in either direction it assumes a different phenomenal form which is usually described as "diamond-shaped", though the basic form of the square is still apparent. In the case of a more complex figure, such as a human face, the change in phenomenal form on inversion is so pronounced that recognition or identification of the individual is rendered much more difficult. It may be inferred, therefore, that the covert influence of the frame of reference immanent in the memory trace complex underlies the variations in phenomenal form which are associated with changes in the orientation of a figure. When a mono-oriented figure is rotated from its usual egocentric orientation a series of directional and polar mismatches is set up between elements of its perceptual image and the comparable elements deriving from either the memory trace of the figure itself or the memory trace of an exemplar of the class to which it belongs.

The experiments concerning perceptual adaptation to a retinally disoriented field of view, which have been carried out by Kohler (1964), Rock, and others, demonstrate that the trace complex can realign itself over a period of time in such a way that phenomenal impressions of uprightness and left and right are restored. It is not unreasonable to suppose that the process whereby the traces of the original complex are replaced by new ones in a different orientation has something in common

with the one taking place during the period when the trace complex is first established.

It is possible to show the intrinsic egocentric framework exists in the form described by comparing its putative influence on the phenomenal form of an isolated figure with the effect of an analogous contextual framework on the same figure. Kopfermann (1930) has provided a useful illustration of the way in which the directional aspects of the contextual framework can influence the phenomenal form of an enclosed diamond or square (Figs. 1.1 and 1.2). In Figure 1.1(b), where the contextual frame provided by the outer rectangle has its sides aligned with both the longitudinal axis of the egocentric frame and the frame provided by the edges of the page, the inner form is phenomenally a diamond. But when the immediate framework is tilted, as in Fig. 1.1(a), the influence of the other two frames is to a certain extent overcome, and although the situation is phenomenally more ambiguous than in Fig. 1.1(b), the figure previously judged as a diamond has, in Fig. 1.1(a), a tendency to take on the appearance of a square. The converse situation is illustrated in Fig. 1.2. In either case, if the contextual frame (the rectangle) is removed then the same two phenomenal forms are seen, when the principal axes of the egocentric frame are aligned with the directions which the contextual frame occupied, as would have been perceived had it not been removed and the sagittal axis of the observer's head had remained aligned with the sides of the page. The optimum conditions for observation of these effects are obtained when the figures are placed within a circular border and the field of view is restricted to the space within it, so that the context is free of strong directional components which would otherwise overcome the effects of the egocentric frame.

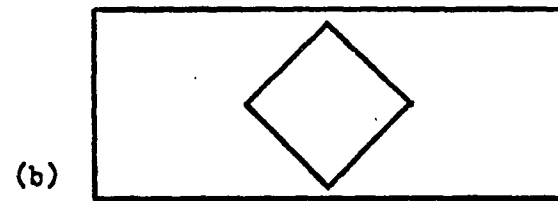
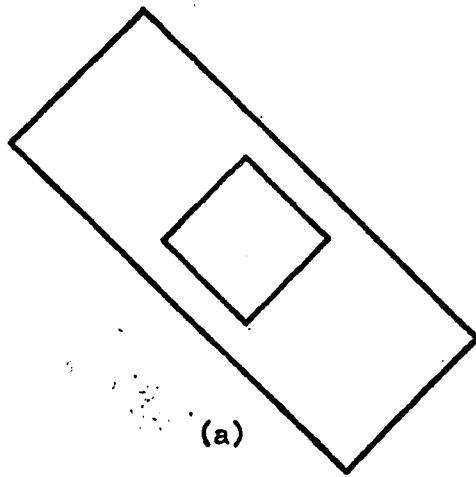


Fig. 1.1. Diamond with contextual frame.

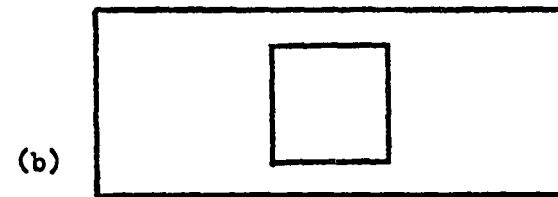
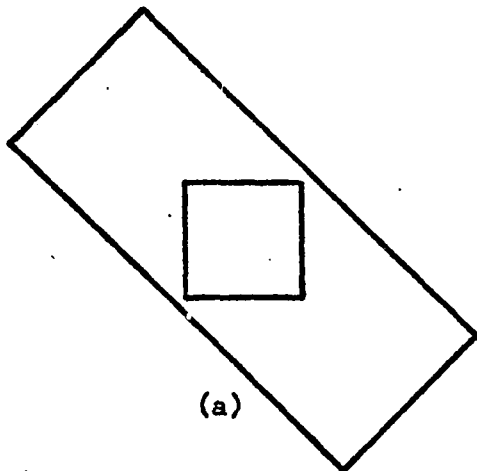


Fig. 1.2. Square with contextual frame.

The directional and polar components of the Cartesian frame have been described in a general way, but it is necessary to consider in greater detail the kind of visual experience that contributes to specific aspects of the frame. The everyday visual environment abounds in vertical and horizontal elements, and there are numerous mono-oriented objects which are symmetric about the vertical axis, at least within one plane (the human body, trees, etc.). However, when one considers the locations of objects within a horizontal plane, or the orientation of a particular object about a vertical axis, it is clear that, with the exception of one class of objects, there are no positions or orientations which predominate. The question arises, therefore, as to how the horizontal axis of the perceptual frame becomes polarized. Amongst the several possible solutions to this question the first that might be considered is that the body image can provide a reference either within the visual modality (a mole on one hand, for example), or cross-modally through kinesthetic awareness of which hand or foot is the dominant one. Alternatively, in cases where reversal and inversion errors were unusually persistent, an artificial extracorporeal contextual reference could be used as the basis for a training technique (Newson, 1955). One disadvantage of all these methods is that they entail a specific act of referral which takes attention away from the figure whose orientation is being judged, and they may also require the use of a mnemonic or code, so it is difficult to see how such procedures could be integrated smoothly and automatically into the reading process. What is more likely, if the general model developed so far is correct, is that the horizontal axis acquires its polarity from the assimilation of graphic material itself. In particular, it would be derived from those letters, such as c and e,

which under spatial transformation do not map onto other members of the alphabet, since their memory traces provide a systematic left-right polarization of the complex. As in the case of the vertical axis, the polarity of the horizontal dimension is a feature abstracted from the complex of orientation-specific memory traces and it exerts a covert influence on the phenomenal form of letters and words. In view of the fact that the child stands and walks (in a vertically asymmetric world) several years before he has regular contact with (horizontally asymmetric) graphic material, the polarity of the horizontal axis does not become established until some time after that of the vertical axis, with the result that letter reversals are more frequent, and persist longer than inversions.

To evaluate whether an inherent visual reference or, alternatively, a body image reference based on kinesthetic memory, underlies the visual perception of orientation one may adduce some evidence from the work of Kohler (1964) concerning perceptual adaptation to a left-right reversed visual field. Typically, the course that adaptation or rehabilitation follows under these circumstances is as follows. Over a period of about two or three weeks disturbances in motor behaviour (reaching, walking, avoiding obstacles, etc.) are gradually overcome, though at the end of that period the world is, visually, still experienced as reversed. Perceptual adjustments come after a further period of time, but they do not take place uniformly in respect of all classes of objects, or, for a given object, at every visual location. Kohler (1964) gives a graphic account of one of his subjects' experiences on the eighteenth day of wearing the spectacles (the experiment took place in a country where vehicles are driven on the right):

"Approaching pedestrians were seen on the correct side, but their right shoulders were seen on the subject's right side. Inscriptions on buildings, or advertisements, were still seen in mirror writing, but the objects containing them were seen in the correct location. Vehicles driving on the "right" (and the noise of the motor agreed) carried licence numbers in mirror writing. A strange world indeed! It is immediately clear that an optical reproduction of this sort is impossible. Either the sides of the street should be reversed along with the number and everything else, or, if we go to the trouble of reversing the numbers alone, the order of the numbers should not change. But even this does not happen, for the subject is capable of localizing both sides of, say, a "3" correctly (open to the left, the curves to the right) and still see it mirrorwise! What is involved here is a split between, on the one hand, a new right-left emerging from kinesthetic experience and, on the other, the simultaneous continuation of old memories of forms of letters and numbers." (p.155).

The subject's experience of the number "3" illustrates in a striking manner how two distinct types of judgment regarding its orientation - one in terms of a body image reference, and the other in terms of an inherent visual reference - may exist side by side and yet produce opposing results. Kohler's interpretation of the phenomenon in the last sentence of the passage quoted above is substantially consistent with the present analysis. When he speaks about "a new right-left emerging from kinesthetic experience" he presumably means that the perceptual adaptation to the reversal of left-right relations, which results in the original relations being restored, takes place through a process of referral to body members which, in the kinesthetic mode, are maintained in the correct left-right relationship throughout the experiment. Now it is clear that in considering adaptation to a left-right reversed field which contains no graphic material the model which was formulated to describe adaptation to an inverted image cannot be applied because, as was pointed out previously, there is no preferred order or orientation of natural objects prevailing within the horizontal

plane. As a consequence of the latter point no fundamental perceptual conflict arises when left-right relations are reversed, insofar as a stationary observer who sees a scene for the first time when wearing reversing spectacles will detect nothing strange or unfamiliar about its visual appearance. Once a hand or leg is moved, however, the left-right reversal is immediately made apparent on account of the visual body image being at odds with the kinesthetic one; as Kohler suggests, adaptation consists of modification of the former image to accord with the latter one. Apparently, the process of adaptation, if not continued beyond a period of about two weeks, still leaves graphic material in its mirror-wise state. It may be dangerous to generalize from one case, but the experience of Kohler's subject suggests, therefore, that knowledge of left and right does not have a fundamental role to play in establishing, on a phenomenal level, the perceived distinction between letters which differ in left-right orientation, although it could presumably support a process which explicitly referred features of the letter to sides of the body. Kohler found that if the experiment continues for a longer period of time changes do occur in the appearance of text:

"Subject Grill (with his longer period of thirty-seven days) went beyond this stage, and eventually achieved almost completely correct impressions, even where letters and numbers were involved. In reading, for example, the first words to rectify themselves were the common ones, whereas those that had to be looked at attentively remained reversed (even though the line of words as such started on the left and ended on the right). After much practice, "mirror reading" became so well established and previous memories so secondary that even print looked all right, as long as attention was not too critical." (p.160).

Thus, the process underlying adaptation to reversed text appears to have a different basis from that involved in adaptation to aspects of the field other than graphic material; in view of the horizontally

polarized nature of text, it may be tentatively concluded that the former process, as opposed to the latter, entails the displacement of old memory traces by new ones, as was proposed (following Rock, 1966) in the case of inversion of the field.

It is a corollary of the above hypothesis that if the intrinsic frame of reference fails to develop in the normal way, then letter orientation errors will occur more frequently and persist for a longer period than usual. When this model was first put forward (Richardson, 1974) it was suggested that the lack of an intrinsic frame could be accounted for in either of two possible ways, though one of the solutions was deemed to be implausible. However, further consideration of the problem revealed that a third explanation had been overlooked, while the two that had been proposed were essentially identical from a psychological point of view.

The first explanation was that "a mono-oriented figure gives rise to memory traces whose orientations vary randomly from one instance of the figure to the next" (p.29). (In fact, this statement applies to the whole field of view; whatever the relationship between the orientation of the proximal stimulus and the orientation of the corresponding memory trace, it is the same function at every location in the field.) It is difficult to envisage a memory trace which lacks a stimulus-copy aspect (i.e., which is not orientation-specific), but such a condition would be easily discovered since an inverted field of view would have the same phenomenal appearance as an upright one. This explanation would be sustained, therefore, if it could be shown that individuals who make reversal and inversion errors do not experience any disturbance in visual perception when they wear inverting spectacles.

As far as is known, there have never been any reports of visual perception being undisturbed under these circumstances, though it is unlikely that any of the subjects who have taken part in the experiments were handicapped in reading.

As to the second explanation, it was suggested that "if a stimulus-copy aspect of the trace is recorded, then the process whereby the structure of the trace complex is abstracted is faulty or absent" (p.29). Now, the distinction between a situation in which the stimulus-copy aspect of the memory trace fails to be registered and one in which it is recorded, but its effects on the phenomenal appearance of things are not realized for some reason, is not apparent at the behavioural or perceptual levels. Since a detailed analysis of the neural aspects of the process is outside the scope of this discussion, even if it were possible, the second solution can be abandoned, or in effect conflated with the first, since its consequences for perception are the same.

Both forms of the solution outlined above are independent of the role of experience in the development of the frame of reference. Now, the horizontal axis acquires its polar features through the visual system's repeated encounters with letters and numbers which exhibit horizontal asymmetry and which, provided the page is always presented in the conventional manner, maintain a unique egocentric orientation. Presumably, a fairly large number of such encounters is necessary before the polarization of the axis is sufficiently well established to make the phenomenal forms of reversible letters easily discriminable. If a child rarely opens a book, or experiences such difficulty with reading that the amount of text he covers is limited, reversal errors might persist to a relatively late age even though there are no

deficiencies in visuo-spatial perception as such. In these circumstances it would be more correct to describe reversal errors as being consequent on the level of reading skill, rather than the result of a perceptual deficiency. This interpretation is supported by the observation that literate adults whose first language is not based on the Roman alphabet and who are studying English as a foreign language sometimes produce reversal errors in the course of their initial attempts at reading and writing.

Up to this point the analysis has been confined to the visuo-perceptual aspects of letter discrimination and recognition, but there is one characteristic of the pattern of children's reversal and inversion errors which has been disregarded and which may not be explicable in terms of the present form of the model. When such errors occur they generally do so in respect of those letters which, under spatial rotation, map onto other members of the alphabet (viz. b, d, p, q; n, u; m, w; h, y). But if the cause of the orientation confusion is located in the visuo-perceptual process, it is difficult to see why other letters (a, c, e, etc.) are not subject to writing reversals to the same extent (the same difficulty does not arise with regard to reading reversals). In order to give an explanation of this effect it may be prudent to take into account aspects of the learning process which have so far not been considered. For the purposes of the argument a somewhat idealized model of letter acquisition may be adopted in which it is assumed that by the age of 7 or 8 years at the latest the perceptual frame of reference has become established, even in the case of retarded readers, and that reversals of "non-reversible" letters (such as c, e, etc.) no longer figure in the child's writing,

although he may still make reversals in naming or writing to dictation letters such as b, d, p, q, etc. The persistence of errors involving these letters would not then be attributed to a difficulty in the discrimination of orientation, but rather, as McGurk (1972a) has suggested, to the fact that there is a higher degree of similarity amongst them than amongst letters which differ in form, with the result that the task of learning grapheme-phoneme associations is more protracted in the former case than in the latter. That it is even more protracted for retarded readers than for good readers would, in terms of this analysis, be construed as a consequence of their difficulty (as opposed to a cause of it), insofar as their exposure to text is, for whatever reason, reduced and there are fewer opportunities for the association to be made. The pattern of errors described above does not apply to all retarded readers as there are certainly cases, albeit infrequent ones, where a child older than 8 years reverses numbers and also letters such as s or z; the interpretation here might well be quite different from the one given in other cases where it is primarily b, d, p, and q which are confused.

Although the theory of orientation perception which has been put forward may not be capable of fully accounting for the usual pattern of letter reversal errors, there is some indirect evidence that the visual frame of reference does play a role in the recognition of letters which differ in spatial orientation. Following Piaget and Inhelder's (1956) study of the child's conception of the vertical and horizontal of physical space, Inhelder (1962) reported that the performance of children with reading difficulties on the water-level and plumb-line tasks which were used to assess these concepts was not as advanced as that of average readers of the same age. Lovell et al. (1964) investigated a

range of cognitive abilities, including performance on axes-of-reference tests, in a group of retarded readers and a group of average readers matched for nonverbal intelligence, social class, school, age, and sex, and were able to confirm Inhelder's finding. Of course, a result of this kind, bearing broadly on reading ability, is too general to be adduced as decisive evidence for the hypothesis under consideration, which is concerned with a relatively circumscribed aspect of reading difficulty. One of the aims of the experimental phase of this study is to determine whether children's performance on axes-of-reference tests is more specifically related to the incidence of reversal and inversion errors.

Now, the system of reference which was the subject of Piaget and Inhelder's (1956) study is one based on the vertical and horizontal of physical space, whereas the framework which subserves the judgment of orientation in the mature reader is one which is intrinsic to the visual system and whose axes are aligned with the principal axes of the head. The young child's lack of success in making correct predictions about the direction of the water level or the plumb-line is attributed to his inability to make use of the frame of reference provided by the jar itself, or a frame external to it. Success comes with the realization on the part of the child that, whatever the angle of tilt of the jar, the water surface or plumb-line preserves its relationship with the direction of other horizontal or vertical elements external to the jar. The child ultimately reaches a stage where physical space is conceptually organized in terms of three mutually orthogonal axes, the system being independent of the arrangement of particular objects within the space at a given moment. Once this level of organization is reached the axes of the

system can be decoupled from the physical horizontal and vertical directions and aligned in whatever manner is appropriate to the task in hand. Thus, for example, the system could function as an egocentric frame subserving reading and writing skills, though it may be argued on the basis of the hypothesis already proposed that, in the case of this particular reference, there is a different developmental route to the same outcome, and it is realized at an earlier age than Piaget and Inhelder's scheme allows. There are further grounds for supposing that the child's conceptions of the vertical and horizontal do not form the basis for the perception of egocentric orientation. First of all, the child's judgment of directions in physical space does not become independent of trial and error referral activities until about nine years of age, approximately one year after most children have ceased making reversal errors. Secondly, it is not the directional aspects of the framework which serve to distinguish letters related through spatial transformation(s), but rather its polar aspects. The quartet: b, d, p, and q, for example, have a vertical feature in common, and are distinguished solely in terms of the relative polar position of the curved feature.

The foregoing interpretation of Piaget and Inhelder's analysis, in which the final operational stage of development is seen as one which enables both contextual and egocentric¹ judgments of direction to be made,

¹ When the term "egocentric" is used in this thesis to describe a frame of reference it does not carry the connotation that the child who possesses such a frame is necessarily at an egocentric stage of pre-operational thought, as the term generally signifies when it is employed in the writings of Piaget and his co-authors. In that context, a child who is egocentric in his representation of the world is limited to his own point of view. However, in this thesis, unless it is stated otherwise, if a child is able to represent a configuration in terms of an egocentric frame it does not necessarily mean he is confined either to his own point of view or to making judgments solely in terms of an egocentric frame and not also a contextual one.

appears to differ from the construction put on it by Bryant (1974). Bryant analyses perceptual development in terms of absolute and relative codes (Koehler, 1918), two concepts which, when applied to the perception of orientation, appear to share features with the egocentric frame and the contextual frame, respectively. In general terms an absolute code presupposes an internal perceptual "standard" which can be used to measure off the value of a particular attribute, such as size or brightness. On the other hand, a relative evaluation of perceptual information involves making a comparison between two, or more, different values of an attribute. The values compared may pertain to objects situated in the same field of view or, if a stable frame of reference for the attribute in question is present, then experiences at different points in time can be related via the process of deductive inference. Now Bryant, having considered the evidence from his own experiments and those of others, concludes that relative codes provide the primary means whereby the young child is able to evaluate his perceptual experiences, and that he is able, only with great difficulty, to handle absolute values. At a later age the child develops absolute codes for some attributes, though even in adulthood some perceptual parameters are not easily registered in absolute terms.

Bryant (1974) considers the order of development for relative and absolute codes described above to be the opposite of that suggested by Piaget and Inhelder:

"Young children of three and four years initially rely very strongly on framework cues, and use them inferentially as an effective way of categorizing and learning from their perceptual experiences: as they grow older they begin to acquire other, more flexible, props, which I shall categorize as internal frameworks, to help them organize their perception. The strategy which Piaget saw as a culmination of perceptual development is, in this alternative view, a very

basic perceptual strategy, whose effects are limited and rather haphazard, and which children already begin to abandon by the time they reach the age of about six years." (p.9)

Insofar as the perception of orientation is concerned, what is referred to in the above passage as reliance on framework cues would amount to noting whether a particular feature of interest is parallel to an element, or elements, in the context. Now, as Piaget and Inhelder (1956) assert:

"Far from constituting the starting point of spatial awareness, the frame of reference is in fact the culminating point of the entire psychological development of euclidean space." (p.416)

but if this statement is to be construed as entailing the inverse developmental sequence from that put forward by Bryant, then it is necessary to assume that when Piaget and Inhelder speak about a frame of reference they are referring to a level of organization of spatial elements which is equivalent to that demonstrated by the child when he makes use of what Bryant terms an "external framework". It seems fairly clear, however, that they are describing the operational level of development, beginning around the age of nine years, in which the sphere of spatial intuition is extended to symbolic objects and, most generally, to positions within space, not just objects occupying these positions. Contrary to what Bryant implies, Piaget and Inhelder have demonstrated that children as young as four and five years can make use of external frameworks, though it is probably correct to say that they would not consider them to be capable of making deductive inferences in which such frameworks are deployed. Thus, referring to children at Substage IIA (aged about 5 years) in the development of spatial reference systems - "Water level shown parallel with the base of the jar and trees

perpendicular to the mountainside" - Piaget and Inhelder give the following description of their abilities:

".....not only can they define the water level as a surface or a plane, but they can also relate this surface to the base of the jar. They are thus beginning to use a point of reference, though a mobile and not yet a stationary one. Now although these discoveries are by no means sufficient for building a frame of reference, nevertheless they constitute the preparation for it..... The children at the present level, in contrast to those of Stage I, have already mastered the use of straight lines and planes under certain conditions (such as when they serve as references to items parallel to them.....), and the way these children relate the surface of the water and the base of the jar shows a rudimentary idea of parallelism....."
(p.390)

Compared with the water level task, Bryant's successive matching task involving oblique lines presents a somewhat simpler problem in that the two-dimensional stimulus figure which was used conveys an immediate impression of parallelism which can be grasped globally in one fixation, whereas, in the earlier stages of development, judging the direction of the water level requires a number of perceptual transports to elements outside the immediate configuration. Nevertheless, even in the former situation, the child's apprehension of parallelism, or in Bryant's terminology, the occurrence of a 'match' signal, takes place through assimilation to an established schema; it is the conservation of this schema, an inherent characteristic of its mode of functioning in Piaget's view, which accounts for children being able later to recognize the line with the same orientation as the standard.

Thus, in certain respects Bryant seems to have misconstrued Piaget and Inhelder's account of the development of spatial reference systems. Not only have Piaget and Inhelder, like Bryant, demonstrated referral activity in young children of four and five years, but they have also

given a description of a framework which, in its fully developed form, has the characteristics of an absolute reference and so makes it possible for the child to dispense with referral activities. What Bryant succeeded in showing was that young children's manifest difficulty in performing deductive inferences is not a result of their failure to grasp the logical principle, as Piaget would probably maintain, but rather may be due to the inaccessibility of the data or an inability to memorize or retain it. Whether Bryant is also correct in stating that the child develops the use of absolute codes, or "internal categories", after he has mastered the use of relative codes, or "external categories", is open to question. Although, as was shown above, Piaget's point of view is reconcilable with Bryant's in this respect, the age at which the former author places the emergence of the operational level of spatial concepts, namely nine years, is apparently not the earliest at which an internal framework is used in perceptual tasks. For instance, Rudel and Teuber (1963) found that 8-year-olds could make successive discriminations between oblique lines - a task in which successful performance depended on recourse to an internal frame since no suitable contextual frame was available - almost as easily as they performed the same task with vertical and horizontal lines. Using a similar task, Bryant (1969) found that even younger children (7-year-olds) were successful. The disparity in age between these children and those participating in Piaget and Inhelder's experiments could be attributed to the fact that, in the water-level and plumb-line tasks the immediate framework of the jar is the primary influence on the child's representation of the configuration, and the effect of the newly-developed internal framework is overcome. However, it is not at all clear that performance on the

Piagetian tasks, on one hand, and those of Bryant, and Rudel and Teuber, on the other, is interrelated in the way that is implied. The proposed model of the internal frame, though it does not necessarily negate it, is based on different ontogenetic principles from those underlying the Piagetian system of reference, which is claimed to be the product of the child's co-ordination of his actions and their internalization in an operational schema. Accordingly, if the former hypothesis is correct, and the origin of the intrinsic frame is independent of the child's conception of physical space, then maturation of these two systems would not necessarily occur at the same age. In fact, there is evidence suggesting that the intrinsic frame is present at a far earlier age than indicated by any of the work mentioned so far.

It has been shown that, before the age of six months, the human infant is sensitive to the egocentric orientation of both geometric and realistic figures. Using Fantz's (1958) spontaneous preference method, Watson (1966) found that infants aged about 14 weeks smiled significantly longer at an upright human face than one oriented at 90 degrees or 180 degrees. However, the time which the infant spent smiling at a "complex stimulus" mask worn by the experimenter was independent of its egocentric orientation. Watson also found that when infants were shown two orientations of a schematic face in a side-by-side position, with one upright and the other rotated 180 degrees, they spent a significantly longer time fixating the upright one. On the other hand, when a "dot" form and a "tee" form were paired with their respective 180 degree variants this technique did not result in significantly different fixation times.

McGurk (1970) questioned the validity of Watson's method, pointing out that subjects who failed to exhibit an attentional preference for a particular orientation might nonetheless be able to discriminate between different orientations. In an attempt to resolve the issue, McGurk (1972a) developed a new variation on the violation of expectancy paradigm (Lewis and Goldberg, 1969), which he first validated on a group of 3- to 5-year-old children who were known to be capable both of discriminating between different orientations of the same form and of recognizing a given form in different orientations. This technique was then employed to assess the same perceptual abilities in infants aged three, six, nine, and twelve months, using abstract line figures as stimuli (McGurk, 1972b). It was found that the infants between the ages of six and twelve months responded in much the same way as the older children had done, suggesting that they are equally capable of perceiving changes in orientation and of recognizing a form irrespective of its orientation. However, it was not possible to draw firm conclusions regarding the capacities of the three-month-old children as habituation of attention did not occur under any of the experimental conditions, and consequently the recovery which might have taken place when the stimulus parameter was changed on the violation of expectancy trial could not be detected. This last result was somewhat unexpected in that it failed to confirm the findings of an earlier study in which McGurk (1970) had used three procedures, namely Fantz's spontaneous preference method, the standard violation of expectancy method, and a modification of the latter, to assess the discrimination of orientation in infants between the ages of six and twenty-six weeks, and had found that they were able to perform this discrimination under the second and third procedures, but not the first. The failure to

replicate the earlier result was attributed to differences in the illumination conditions obtaining in the two experiments.

Robertson (1975) used a visual habituation method to investigate the ability of 6-month-old infants to discriminate a change of 90 degrees in the orientation of a rectangular bar within the fronto-parallel plane. Two situations were compared, one in which the orientation of the bar was changed from vertical to horizontal, and the other where it was changed from 45 degrees clockwise to 135 degrees counterclockwise. He performed three experiments in each of which the bar was surrounded by a frame of a different shape - rectilinear, diamond-shaped, and circular. It was found that infants could discriminate both types of change equally well, and furthermore that the type of framework did not affect their performance.

Once children begin to acquire language other methods can be used to assess their abilities. In the study by McGurk (1972a) cited above it was shown that, when questioned directly, children as young as three years have no difficulty in judging whether pictures of familiar objects, viewed in a horizontal plane, are the right way up. A similar finding was reported by Light (1974), who also showed that some three- and four-year-olds can adopt a perspective other than their own in judging whether a figure is correctly oriented.

Thus, there is a substantial body of work indicating that, in certain situations, the young child can respond in a way which suggests he possesses an absolute code, or internal category, for orientation. Whether he is equally sensitive to changes in the relative position of objects is less clear, although in some of the experiments described above the transformations applied to stimuli evidently involved changes

in polar properties, as well as directional ones (e.g., in McGurk's (1970) experiment, inversion of the stimuli (a three-dimensional model of a face and a two-dimensional funnel-shaped object) involves an alteration in the relative position of their internal features, in addition to changes in directional properties.) As suggested earlier, the polar aspects of the egocentric frame might play a more important role in the recognition of letters such as b, d, p, and q than do the directional components, so that experiments concerned with the discrimination of spatial position may contribute more to an understanding of the process. In this connection, Asso and Wyke (1970) employed figures composed of line elements and circles which were placed in various spatial relationships to each other (one over the other, one to the left of the other, etc.). Visual discrimination was assessed in three age groups (mean ages: 5:1, 6:1, and 7:2) by means of a matching-to-sample procedure in which the child chose the correct figure from amongst the whole set of figures. The percentages of correct responses obtained by the 5-, 6-, and 7-year-old groups were 65.0, 86.8, and 98.3, respectively.

In Bryant's (1974) experiment the figure to be discriminated was a square containing a single dot which was placed in one of four positions relative to the centre, that is, either above, below, to the left, or to the right. A simultaneous two-choice matching task was used in which the sample card was placed between the two choice cards, the incorrect choice always being the mirror image (in a plane perpendicular to the axis of displacement) of the correct choice. Each set of cards was presented in both a horizontal array and a vertical array. As a result, when the array was aligned horizontally the three dots in a left-right discrimination were all aligned with each other, whereas for an up-down

discrimination the incorrect dot was out of line with the sample and the correct dot. The converse situation obtained when the array was vertically aligned. The task was presented to groups of 5-, 6-, and 7-year-old children, and it was found that, overall up-down discriminations were no more difficult than left-right ones. However for both relations performance did depend on whether the array was an in-line one or an out-of-line one, the former situation being considerably more difficult than the latter, at least for the 5- and 6-year-olds. For the purposes of making a comparison with Asso and Wyke's experiment, where the arrangement of the figures was such that the out-of-line cue was not present, it is appropriate to consider Bryant's results for the in-line situation. Combining the scores for up-down and left-right discriminations, which are given separately in Bryant's table, and converting the error scores (out of 20) to percentages of correct responses, then the following figures are obtained for the 5-, 6-, and 7-year-old groups respectively: 67.3%, 74.9%, and 86.5%.

Bryant believes that the out-of-line situation is easier for children because it can be solved by noting the relative position of the dots to each other without necessarily taking account of each dot's position relative to its square. He implies that the child would need to identify the positions of the dot as left, right, up, or down, as the case may be, in order to perform the in-line task successfully, and that his ability to do so indicates that an absolute code has been acquired. However, bearing in mind that the task involved a simultaneous, rather than a successive, discrimination, it is conceivable that the child could have succeeded without the aid of an absolute code, provided he could at least differentiate one side of the square from the other and

maintain the distinction as he transferred his attention from one square to another, possibly with the aid of a framework cue in the background. A more rigorous test of the presence of an internal category for position would be one involving a successive discrimination under conditions where framework cues are eliminated in order to prevent the child from reaching a solution through a process of inference. That there is more to the recognition of letters differing in orientation than is exhibited in a simultaneous position discrimination task is apparent from Asso and Wyke's (1970) study: at the age of 6+ when the success rate on the latter task is 86.8%, children obtain only about 30% correct responses when asked to name or write to dictation spatially confusable letters. Though factors other than the lack of an absolute code for position may account for these different levels of performance, it would be necessary to carry out an experiment along the lines suggested above before one could be certain about the age of emergence of the polar components of the internal frame of reference.

The child's conceptions of left-right and before-behind relations in space have also been investigated by Piaget and Inhelder (1956), in an experiment designed to demonstrate that projective and euclidean concepts develop in a concurrent manner. In one of the two methods used the child either constructed a model of a village by copying an arrangement already laid out, or drew the model from a given viewpoint. Piaget and Inhelder noted the following stages of development. In Stage I (up to 4 years) the child is unable to achieve correspondence between either the number, the position, or the order of the objects in his layout and those in the model. During Stage II (4 years up to 6-7 years, on average) the child organizes objects in small independent groups, with

certain relationships taken account of within groups, but only rarely or by accident between the groups or between a group and the edge of the base. No account is taken of distance or perspective, while reversals of left-right and before-behind relations sometimes occur. During Stage III (7 to 10 years) a stable system of reference is gradually established. In the first Substage (IIIA), from 7 to 8 years, the child's arrangement of objects consistently takes into account both before-behind and left-right relations. Substage IIIB is characterized by the child's improved performance in regard to distances and proportions. Finally, in Stage IV, with the development of formal operations, the child's drawing takes on a diagrammatic form with learned conventions replacing many of the natural concepts. What is of interest with regard to the present analysis is the age at which the child's representation first displays consistent awareness of the left-right relationship of objects in the layout. This development occurs some 1 to 2 years after the child is able to name the left and right sides of his own body, but it appears to coincide quite closely both with his first successful attempts at judging the egocentric orientation of a line (Rudel and Teuber, 1963; Bryant, 1969) and the disappearance of reversal errors from his reading and writing. Moreover, notwithstanding the reservations expressed about the validity of Bryant's (1974) method, the age (7+) at which his subjects were considered to have acquired an absolute code for position corresponds quite closely with the age of accession of Piaget's subjects to Stage IIIA.

Assuming that an inherent lag in maturation is, in some instances, responsible for impeding the child's progress in learning to read and spell, it seems reasonable to suppose that the characteristic anomalies

of behaviour, perception and language which are said to accompany the difficulty are capable of being interpreted in a way which reveals their common origin. An attempt to formulate such a program was made in an earlier paper (Richardson, 1974), the model of a visual frame of reference being used to extend the analysis to the following areas of development:

- (a) The recognition of complex mono-oriented figures (words and faces) under spatial transformation,
- (b) The acquisition of temporal relations and conventionally-ordered series; the comprehension of bipolar relations (non-spatial and non-temporal adjective-antonym pairs),
- (c) Visual-sequential scanning of text,
- (d) The maintenance of postural stability.

Only the first two functions above will be considered in this thesis, and the reader is referred to Richardson (1974) for that part of the analysis relating to (c) and (d).

1.3 The recognition of complex figures (words and faces) under spatial transformation

If a mono-oriented object is turned upside-down, or if the whole field of view is inverted, most observers report that their phenomenal appearance is altered. This change is particularly noticeable in the case of two categories of object, viz. human faces and text, though with regard to the latter, there appears to be considerable individual variation in the degree to which reading speed is reduced, a small proportion of individuals even maintaining complete fluency.

Rock (1966) is of the opinion that the change in phenomenal form resulting from inversion of a figure is unrelated to its perceived egocentric orientation:

"Suppose Stratton, while wearing the inverting lenses, viewed the scene with his own head inverted. Now the images of objects would return to their normal retinal orientations (because he would be reinverting the lens-inverted image) with the direct result that material such as text or script would immediately be recognizable again. He would perceive them as if they were upright in relation to himself (i.e., upside down in space as he now is) but, in doing so, his perception would not be veridical. The objects are upright in space and not upright with respect to him, and true adaptation would require perceiving them accordingly. Therefore, the normal vs. strange appearance of shapes is not to be confused with their perceived egocentric orientation. With sufficient experience, familiar objects would undoubtedly cease appearing strange (because, I believe, new traces in the new orientation in the substrate are acquired), but this does not imply a righting of the scene." (p.64)

In other words, Rock would maintain that an upside down object could lose the phenomenal appearance associated with that orientation, but nevertheless still be perceived as upside down. Yet, in his analysis of adaptation to an inverted field of view, Rock attributes the gradual restoration of the familiar appearance of the world which was evidently experienced by some of the subjects, to the acquisition of new traces in the neural substrate. If the orientation of these traces is a one-to-one function of the egocentric orientation of the corresponding stimuli, then presumably as they displace the old traces they create a new reference for the veridical perception of uprightness. Therefore, if one wished to argue, as Rock does, that an object could be perceived as upside down and at the same time present the normal phenomenal form associated with uprightness, then it would imply that less reinforcement of the trace complex is required to eliminate "strangeness" than to establish veridically upright perception.

The flaw in Rock's argument is apparent in the passage quoted above. When he considers what would happen if Stratton viewed the scene with his head inverted Rock is evidently referring to a pre-adaptation phase of the experiment, possibly just after the spectacles have been fitted, because he goes on to point out that in this position Stratton would see text in its familiar and recognizable form. If text had looked strange when Stratton was in this position it would presumably have looked familiar and recognizable when he was upright, a state of affairs which constitutes perceptual adaptation. However, Rock then proceeds to contrast the way things look to Stratton in that state with their expected appearance if "true adaptation" had taken place, losing sight of the fact that the initial description he gave of Stratton's situation and phenomenal experience was not consistent with such a state. In any event, this issue cannot be resolved by determining what occurs at the level of the neural substrate, but only by establishing exactly what subjects who wear inverting spectacles experience.

The foregoing remarks concerned a situation in which the whole visual field undergoes inversion. They also apply in respect of an isolated mono-oriented object rotated against a homogeneous background, or text, regardless of the nature of the background, but somewhat different considerations apply in the case of a mono-oriented object situated in an environment, like that of the everyday world, which is vertically asymmetric. When such an object is tilted, the observer remaining upright, there is a change in phenomenal form which can be attributed either to the new egocentric orientation of the object or to the fact that its relation to the context has changed. In one of Rock's experiments these two factors were separated, and it was shown that the

change in phenomenal form is predominantly due to the changed relation of the object to the context. However, Rock noted that this finding did not hold true for text in that ease of recognition depends solely on its egocentric orientation, a remark which also applies to the human face.

There have been one or two reports suggesting that retarded readers do not experience a decrement in recognition performance when certain classes of figures are inverted. For example, Critchley (1970) observed that a number of dyslexic children in his series were able to read inverted text with no more difficulty than upright text. Tansley (1971) exhibited a retarded reader's self portrait which, notwithstanding the fact it had been drawn upside down, had been rendered in a very lifelike way. Now, it is possible to demonstrate that the kind of facility with inverted figures displayed in these instances may be associated with the failure of the visual frame of reference to establish itself in the usual way. If an individual is able to recognize a complex mono-oriented figure with equal ease in all orientations, it would imply that the figure's phenomenal form is more or less invariant with respect to orientation. It may be recalled from the analysis presented in the previous section that the egocentric frame of reference is not believed to enter directly into perception or imagery, but rather to make itself felt through its influence on the phenomenal form of a figure. The neural process associated with a mono-oriented figure which is displaced from its usual egocentric orientation is at variance with the structure of the trace complex associated with that class of figure, and, depending on the degree of disparity, a modification of its phenomenal form is produced. The variation which takes place in the phenomenal form of a figure as its egocentric orientation changes enables the latter parameter

to be judged in terms of the former attribute. However, while this process facilitates the judgment of orientation, and in particular the discrimination of spatially confusable letters, it also has the consequence that some classes of mono-oriented figure are more difficult to recognize when displaced from the upright position.

On the other hand, if the perceptual world of some individuals is such that the phenomenal form of a figure is invariant with respect to orientation, then although one means of judging orientation is precluded, it also follows that the recognition of a complex mono-oriented object is unaffected by displacement from its normal orientation. Of course, in many situations the visual context will also exert an influence on the phenomenal appearance of things, but there are some circumstances in which the effects of the contextual frame are minimal and those of the egocentric frame predominate. Such conditions are realized in the following situations: (a) an isolated mono-oriented object seen against a homogeneous background, (b) text and the human face, in any context, and (c) the total field of view. What the preceding analysis has shown, therefore, is that the perceptual deficit which is responsible for retarded readers' letter orientation errors may also result in their apparently superior ability to recognize inverted objects.

1.4 The acquisition of temporal relations and series; the comprehension of bipolar relations

The acquisition of conventionally-ordered series - the months of the year, the alphabet, multiplication tables, etc. - presents considerable difficulties to some retarded readers (Critchley, 1970; Rabinovitch,

1962; Saunders, 1962). There is also evidence, albeit slight, that concept reversals occasionally occur in both their oral and written language; for example, when an antonym is substituted for the correct adjective or adverb, or when a word referring to the past is substituted for one referring to the future, although it is not known whether the incidence of such errors differs markedly from that in the general population.

Considering first of all the acquisition of bipolar relations, it was proposed (Richardson, 1974), in the case of one class of relational terms, that the semantic differentiation of a comparative from its opposite (and also of the underlying adjective from its antonym) rested on a correspondence being established between the lexical attributes, marked/unmarked, and an imaginal representation of the polar components of the spatial framework. This model was suggested by DeSoto et al.'s (1965) finding that, in solving syllogisms involving comparative relations, a majority of subjects ascribed the elements of the premises to positions on a mental image of either the vertical or the horizontal axis. For certain comparatives the vertical axis was generally preferred for representing the relation, and furthermore one direction or pole was fairly consistently used to representing the marked term and the opposite direction used for the unmarked term. However, for other comparatives, neither axial nor polar components of the framework were used in a consistent manner to represent the two members of the relational pair. When these two classes of comparative, viz., consistent relation terms and inconsistent relation terms, were examined it was found that the latter all described parameters which could be invoked directly through visual imagery, whereas, with one exception, none of

the former group was perceptually given. (The two groups of words are also distinguished by virtue of the fact that consistent relation words are generally marked-unmarked pairs, while inconsistent relation words are marked pairs (Jones, 1970).) These considerations led to the hypothesis that the semantic differentiation of certain adjective-antonym and adverb-antonym pairs which do not denote perceptual attributes depends on the members of the pair being mapped in a one-to-one fashion onto components of the spatial frame of reference. Of course, the relations above-below and left-right, which are both perceptually given (the former by virtue of relations given in the field of view, and the latter through a perceived asymmetry in either the kinesthetic or visual body image) would nevertheless be expected to be assigned in a consistent manner, and DeSoto et al. found that this was indeed the case. In this connection, it may be noted that children's comprehension of spatial relations (over, under, beside, between, left, right) develops some time after their ability to make visual discriminations between line drawings which depict the same relations (Asso and Wyke, 1970). However, in the same study, it was found that there was no correlation between scores on the visual discrimination test and scores on the verbal comprehension task.

DeSoto et al.'s findings concerning the relation earlier-later (an unmarked-unmarked pair) are of particular interest in that they may point to the processes which underlie not only the comprehension of a variety of words involving the dimension of time, but also the acquisition of temporal series, such as the days of the week. In a subsequent paper by the same authors, Handel et al. (1968) reported that over 70% of their subjects used a consistent spatial assignment for the relation earlier-later. Although this result conforms with the rule that consistent

relation terms do not denote attributes that are perceptually given, it is not clear, in view of the fact that the theory being proposed applies only to marked-unmarked pairs, how a relation which does not carry this distinction could be associated with the top-bottom or left-right directions in a consistent manner. It suggests that the members of the pair are semantically differentiated in some other way, and that the association of early with the top or the left pole of the frame, and late with the bottom or right pole, merely reflects the fact that the most obvious and natural convention for subjects to adopt in a spatial assignment task is the one governing the layout of text. Whether this consideration constitutes a serious objection to the proposed model depends on which types of relation, if any, are found to be most subject to confusion by retarded readers, though the clinical evidence which is available tends to indicate that it is temporal relations which are particularly affected.

Next to be considered is an aspect of language closely related to temporal relations, namely that of temporal series. The elements which make up the calendar differ from other items in the lexicon in that, while each one usually has distinctive connotations, they derive their denotative meaning from the position they occupy in a conventionally-ordered series, and this ordering relationship is not generally revealed in discourse which refers to them. The child's acquisition of a series such as the months of the year, therefore depends on there being opportunities for him to rehearse the series as a whole, a procedure which, though conceivably based on a universal psychological process, nevertheless takes place under a wide variety of conditions and circumstances, with the result that there is a considerable range of individual variation in the age at which success is achieved.

The classical view of the process underlying the rote learning of a series is that associations are formed between successive items of the series (Ebbinghaus, 1964). An alternative proposal which has been advanced relatively infrequently in recent years (Asch, Hay and Diamond, 1960; Ebenholtz, 1963a, b; Shulz, 1955; Young, 1962; Wishner, Shipley and Hurvich, 1957; Woodworth and Schlosberg, 1954, p.711) is based on the assumption that a series may be acquired by learning the location of items in relation to the beginning and end of the sequence. Perhaps the most successful demonstration of the proposition that serial learning is mediated by temporal position is provided in the work of Ebenholtz. However, he concluded that both the position-mediated process and the associative one have a part to play, though exactly what contribution each makes is not yet clear.

Ebenholtz (1963a) envisaged that a spatial model might serve as an analogue for serial learning in that temporally adjacent items of the sequence could be placed in one-to-one correspondence with spatially contiguous locations on a straight line. The results of Ebenholtz's first experiment would appear to sustain the psychological reality of the process. Its purpose was to present subjects with a serial task which prevented them from forming sequential associations, and this condition was achieved by using a position learning task. The subject viewed a vertical array of 10 windows in which there appeared one at a time in a predetermined order a set of 10 nonsense syllables, and his task was to learn each item on the basis of its position. The window which was to be responded to at each point in the trial was indicated by the appearance of a red rectangle. It was arranged that consecutive items in the temporal order of presentation, determined by five orders

of a ten-item Latin square, never occupied adjacent windows. Thus the experiment essentially involved a position-nonsense syllable paired-associate learning task, with position randomly distributed.

The apparatus devised by Ebenholtz also allowed presentation of a conventional serial learning task, by displaying the items consecutively at the same window. Now, if a serial learning task is facilitated by assigning items to a location, then transfer to this task from the position learning task should occur more readily when there is a one-to-one correspondence between the temporal order of items in the serial learning task and the spatial order of items in the position learning task (i.e., the first item in the serial learning task being associated with the top window of the array, and so on), than when there is no such correspondence. But if serial learning is not mediated by position, the degree of temporal-spatial correspondence of the two sequences should have no effect on the degree of transfer between the two tasks. In order to test these two alternatives, Ebenholtz examined transfer between a serial learning task and a position learning task, and vice versa, under two conditions, one (condition C) in which there was one-to-one correspondence between the temporal position of an item in the serial learning (SL) task and the spatial position of the item in the position learning (PL) task, and a second (condition D) in which there was a random association between the temporal position and spatial location. To evaluate the possibility that sequential associations might be formed and transferred, despite the fact that the PL task was designed to minimize the likelihood of such an occurrence, a third condition (R) was introduced in which inter-item relationships were maintained in going from the SL task to the PL task and vice versa, but the two sequences were displaced with respect

to each other, with the first item in the serial task appearing at window number eight in the position task. If transfer occurs as readily under condition D (which did not preserve either correspondence of position, or inter-item relationships, in going from the first task to the second) as it does under condition R (which preserved inter-item relationships only), then it may be concluded that sequential associations play no part in serial learning.

Ebenholtz found that transfer did indeed occur in going from the SL task to the PL task, and vice versa, and furthermore that the degree of transfer was significantly greater in condition C compared with condition D. That this difference was due to the facilitating effect of position correspondence rather than the maintenance of inter-item relationships was suggested by the further finding that while condition R facilitated a somewhat greater degree of transfer than condition D the difference was not on the whole significant. Ebenholtz concluded that transfer was primarily mediated by item position but that there was also a contribution from sequential associations. The relative contribution of the latter might, in general, be a function of the properties (associativity, meaningfulness) of the items making up the list.

In a subsequent study Ebenholtz (1963b) tackled the same problem using somewhat different methods, and reached similar conclusions. One experiment was designed to determine whether there was evidence of negative transfer under conditions where one would expect interference if associations are in fact formed between successive items of a series. Subjects learnt two serial lists of nonsense syllables (initial and transfer) by the anticipation (spelling) method. For one group, new

items were substituted in alternate positions only of the transfer list, but the rate at which they were learnt was no different from that found in another group who learnt the same "transfer" list, but whose initial list was completely different. According to Ebenholtz this finding demonstrates either that associative interference does not occur in serial learning, or, if it does, that its effects were obscured by the particular conditions obtaining in his experiment.

In summary, recent experimental work on syllogistic reasoning and serial learning suggests that both the semantic differentiation of one class of adjectives from their respective antonyms, and the acquisition of series may be subserved by spatial imagery. The corollary of this hypothesis is that a deficiency in spatial representation might be responsible both for errors in which an antonym is substituted for the correct word, and for difficulties experienced in the acquisition of conventional series, such as the months of the year. However, there would appear to be more justification for the argument that spatial imagery subserves serial learning than there is for the hypothesis that it forms the basis for semantic processes.

Chapter 2

2.1 Introduction

With a view to evaluating a number of hypotheses based on the analysis of Chapter 1 two groups of subjects were recruited, one composed of children retarded in reading and the other consisting of normal readers who were individually matched to members of the first group for various characteristics related to reading ability. The assumption underlying the selection procedure is that the reading difficulties, and also any associated cognitive deficiencies, are unlikely to be explicable in terms of the factors which are controlled for. Of course, any differences in perceptual or cognitive performance which are found may be secondarily related to factors which were not taken into account in the matching process. For instance, in the present study no assessment has been made of the emotional status of the child or the effectiveness of the teacher (in part, a product of pupil-teacher interaction). However, this kind of limitation does not seriously interfere with the object of the study, which is not to enquire into the causes of reading difficulties, but to obtain a description of retarded readers' perceptual and cognitive abilities, in order to relate it to a theoretical model. If the model is adequate it should be capable of being interpreted in a manner which is consistent with whatever etiological conditions and circumstances are found to be significant.

The first part of the chapter is devoted to an account of the technique used to define reading retardation, a description of the tests employed in the screening procedure, and discussion of the

considerations underlying the choice of control variables. It continues by outlining the schedule for the recruitment operation, which took place in local maintained schools, and describes the results obtained on the screening measures by those identified as retarded readers and normal readers respectively. In the second part of the chapter the matched groups of retarded and normal readers are described in terms of the factors which were controlled: IQ, social class, size of family, school attended, and length of schooling.

2.2 The selection of retarded and normal readers

Reading retardation was defined in accordance with the method used by Rutter, Tizard, and Whitmore (1970) in their survey of all 9- to 12-year-old children living on the Isle of Wight in 1964-5. Recognizing the defects in measures such as the achievement quotient, Rutter et al. used a multiple regression technique which, in providing an estimate of a child's reading age, takes into account in a more satisfactory manner the relationship between reading ability and intelligence obtaining in the population under study. Thus, if the distributions of age, intelligence, and reading ability, and their intercorrelations, are known in a sample from the population, and certain statistical conditions are fulfilled, it is possible to derive a formula (the multiple regression equation) which expresses the expected value of one variable (the criterion variable - in this case, reading ability) in terms of the other two (the predictor variables). Since this estimate takes into account the observed correlation between intelligence and reading ability, then if a child's reading age differs from the value predicted by the regression equation, such a difference must be due to

factors other than intelligence. In the Isle of Wight (IoW) study children were designated as retarded in reading if either their reading accuracy age or their reading comprehension age (Neale Analysis of Reading Ability) fell 28 months or more below the level predicted on the basis of their chronological age and IQ (given by the short form of the Wechsler Intelligence Scale for Children (WISC)). The majority of children who are retarded in reading are also backward in reading, that is to say, their reading ability is below the average level of achievement of children of the same chronological age, irrespective of intelligence. However, not all backward readers are retarded readers; reading difficulty may, as often as not, be associated with poor intellectual ability. If the multiple regression equations describing the IoW sample are to be used to make predictions about the reading ability of individuals from a different population, then it is valid to do so only provided it can be shown that the distributions of the criterion and predictor variables, and their inter-correlations, are comparable in samples drawn from the two populations. The extent to which this assumption is satisfied in the case of the Cambridge children will be given further consideration later in this chapter.

In a large scale survey it is obviously impractical to identify the handicapped by administering individual tests to the whole population, and therefore essential to carry out a preliminary screening in order to pick out those children most likely to meet the criteria for the relevant conditions. Thus, in Rutter et al.'s study children with intellectual or educational disabilities, including reading retardation, were selected by means of a two-stage procedure. The

first stage involved a multiple screening process in which five group tests were undertaken by the whole population of 9- 10- and 11-year-olds. This battery was made up of verbal and non-verbal tests of intelligence, a mechanical arithmetic test, a reading test, and a form copying test, and as a further check teachers were requested to note children who were markedly backward in schoolwork. A child was selected for the second stage of individual testing if (1) his score on any test fell two or more standard deviations (SD) below the mean score obtained by children in that age group, or (2) there was a discrepancy of two or more SD between his score on either of the IQ tests and his score on either of the attainment tests, or between his scores on the verbal IQ test and the non-verbal IQ test. A child was also selected for individual study if he obtained a low score on the form copying test, or if he was reported to be markedly backward in schoolwork by his teachers. Children who met at least one of the foregoing criteria went on to perform the short form of the WISC, the Neale Analysis of Reading Ability, and the Schonell Graded Word Spelling Test, Form A. The criteria for inclusion in the three disability groups, namely reading retardation, reading backwardness, and intellectual backwardness, were framed in terms of the results obtained on the first two of these tests.

In the present study, the intention was to select a small group of 8- to 11-year-old boys, meeting the criterion of reading retardation adopted by Rutter et al., with a view to their undertaking a series of tests related to the hypotheses under investigation. Even though the number of schools involved was only about one-fifth of the number surveyed in the IoW, it was apparent that the time available would not permit every child in the relevant age range to be screened. A

preliminary selection (Stage I) was therefore made on the basis of an evaluation by teachers of the children's abilities and levels of attainment. At each school visited an initial meeting was held with class and remedial teachers in order to explain the aims of the study and request their cooperation. The more or less standard protocol which was used to convey to teachers the type of educational handicap being studied did not refer to either reading retardation or dyslexia as such, as these terms are not universally interpreted in the same way. Instead, the difficulty was described as one in which the child's attainment in reading and spelling falls below the level that would be expected in the light of his abilities in other spheres. In evaluating a child's general abilities it was suggested that the teacher might take into account not only his oral language and arithmetic, but also constructional and artistic abilities. It was pointed out that the description could apply equally to a boy of average intelligence whose reading age was considerably below his chronological age, and to a boy of superior intelligence who was reading at a level corresponding to his age. If a teacher enquired whether children who were retarded in reading, or dyslexic, were in fact being sought for the study, it was admitted that these terms were acceptable.

Children who were considered to meet the description given were further assessed using a procedure which was closely modelled on that of Rutter et al. (1970). In planning Stage II of the screening procedure the group tests used in the IoW survey were first of all evaluated in order to determine their suitability for use in the present study. Of this group of tests (see Table 2.1, adapted from Appendix 2 of Rutter et al. (1970)), Verbal Test BC and Verbal Test CD were not considered

Table 2.1 Educational screening tests used by Rutter et al. (1970)

(a) Nine- and ten-year-old groups		(b) Eleven-year-old group	
Test	Total time of Admin.	Test	Total time of Admin.
NFER Verbal Test BC (formerly Primary Verbal Test 1)	40 min.	NFER Verbal Test CD (formerly Primary Verbal Test 2)	45 min.
NFER Non-Verbal Test BD (formerly Non-Verbal Test 5)	40 min.	NFER Non-Verbal Test BD (formerly Non-Verbal Test 5)	40 min.
NFER Reading Test AD (formerly Sentence Reading Test 1)	20 min.	Survey Reading Test NS6	25 min.
Mechanical Arithmetic Test 1C	30 min.	Survey Arithmetic Test NS10	30 min.

Table 2.2 Group tests used at Stage II of the screening procedure

Test	Age Range	Reliability	Standard Error	Timed/ Untimed	Total Time of Admin. (mins.)
First Year Junior					
NRIT (Young)	6:7-8:11	0.95	-	Untimed	60
GRT (Young)	6:0-10:0	-	-	Timed	20
EPVT 2	7:0-11:11	0.92	4.25	Untimed	30-40
Second - Fourth Year Junior, First Year Secondary					
EPVT 2	7:0-11:11	0.92	4.25	Untimed	30-40
CPM	5:6-11:0	-	-	Untimed	20
NFER AD	7:6-12:1	0.94	3.60	Timed	20
GWST (Schonell)	5:0-15:0	0.96	-	Untimed	15-40

suitable measures of verbal ability in retarded readers since the questions in both tests are given in written form. Indeed Rutter et al. (1970, Table A2.1, p.388) give the intercorrelation between Verbal Test BC and Reading Test AD as 0.90, and that between Verbal Test CD and Survey Reading Test NS6 as 0.81. Their unsuitability is further apparent when the results obtained from the IoW group screening are examined. Rutter et al. (1970, Table 3.14, p.37) identify the "sources" by which the 86 retarded readers (identified as such at the individual test stage) were selected for further individual testing. It was perhaps not surprising that the largest number (57 in total, 10 exclusively) was selected by virtue of the fact that their scores on the group reading test were two or more SD below the mean, but the second largest group (46 in total, 4 exclusively) was selected on account of their verbal test scores. On the other hand, not one retarded reader was apparently selected on account of a verbal IQ score-reading score discrepancy of two SD or more, confirming that verbal ability and reading ability are confounded to a significant extent in Verbal Test BC and Verbal Test CD.

Twenty-four retarded readers (one exclusively) were selected because their scores on the non-verbal IQ test were two SD below the mean, and a further 17 (3 exclusively) were selected on the basis of a two SD discrepancy between their non-verbal score and their reading score. The only reading matter with which the child is confronted in taking Non-Verbal Test ED is the set of instructions (which are also read out by the examiner) and an instruction at the end of each sub-test requesting the child not to turn the page until told to do so.

This test would therefore have been suitable for use with children above the age of 8 years (the lower limit of the range for which norms are given), but it was eventually decided to use an alternative (see below), even though a non-verbal test was dispensed with altogether in screening children below the age of 8 years.

The standardization of NFER Reading Test AD covers the age range 7:6 to 11:1, but there were a number of children in our study, reaching the end of the fourth year at Junior School, who were beyond the upper limits of this range. Nevertheless, it was possible to extend its range to 12:1 by the use of an extrapolation formula supplied by the National Foundation for Educational Research. This measure enabled all fourth year Junior children and also a number of boys in the first term of the first year of secondary schooling who were screened for inclusion in the control group to be assessed by means of the same test. Use of Reading Test AD with first year Junior children would have been possible, though not entirely satisfactory (particularly in the case of retarded readers) on account of its reduced discrimination. However, the need to use Reading Test AD for this age range was obviated as the schools concerned generously made available the results of the 7+ survey which all children in the County of Cambridgeshire take in the first term of their first year in Junior School. The survey, which enables the Remedial Service to determine the most effective way of deploying its team of peripatetic teachers, employs two tests - the Non-Readers Intelligence Test (NRIT) and the Group Reading Test (GRT), both constructed by Young (1964, 1968). The former test has four sections: vocabulary, categories, analogies, and opposites, and the published norms give Intelligence Quotients for the age range 6:7 to 8:11. The

Reading Test, which is made up of a combination of word recognition and sentence completion items, provides a standardized score and covers the age range 6:0 to 10:0.

The use of the remaining two tests in the IoW screening battery, namely the mechanical arithmetic test and the form copying test, resulted in the selection of only two retarded readers not selected by the other three tests. By omitting these two tests, therefore, an appreciable saving in testing time could be achieved, without significantly reducing the efficiency of the screening process. Any such reduction, provided it is not so drastic as to affect the degree or type of reading retardation, would be of no consequence in the recruitment phase of the present study, which is not concerned to establish exactly the prevalence of reading retardation, but only to select a group of boys who are retarded in reading to a specified degree.

The foregoing evaluation of Rutter et al.'s group testing procedure led to the conclusion that an effective screening instrument would be provided by three of their five tests, namely the verbal test, the non-verbal test, and the reading test. However, neither of the two verbal tests, BC and CD, were considered suitable for our use for the above reason, and a replacement was therefore sought. In the event, Non-Verbal Test BD was also dropped, though it met all the requirements, so that Reading Test AD was the only test retained. The two tests adopted as replacements were suggested by the Senior Remedial Advisor for Cambridgeshire, and are the ones used by the remedial teaching team for the assessment of children with reading difficulties. The verbal test

is the English Picture Vocabulary (EPVT) Test 2 (Group Form), constructed by Brimer and Dunn (1962), which covers the age range from 7:0 to 11:11 and provides a measure of oral vocabulary which is not dependent on the child's level of reading skill. The authors give the intercorrelations of the EPVT standardized score with the Stanford-Binet IQ and Vocabulary score as 0.805 and 0.810 respectively (based on a representative sample of 124 children aged 10:9 - 11:3). The non-verbal test is the Coloured Progressive Matrices (CPM), Sets A, Ab, B, (Book Form) (Raven, 1965). This test requires the child to complete a series of diagrams by choosing from amongst six alternative pieces, correct performance being dependent on ability to take account of the spatial properties of the pattern (Sets A, Ab, and B (items 1 - 5)) and to reason by analogy (Set B, items 6 - 12).¹ According to Martin and Wiechers (1954) the intercorrelations between scores on Coloured Progressive Matrices and WISC Full Scale and Performance IQs are 0.91 and 0.83 respectively. The two WISC subtests giving the highest intercorrelations with Coloured Progressive Matrices were Block Design ($r = 0.74$) and Object Assembly ($r = 0.73$). (It is the latter two subtests from the Performance Scale which, together with Vocabulary and Similarities from the Verbal Scale, make up the short form of the WISC.) The choice of Coloured Progressive Matrices was mainly governed by the fact that its administration time was about 50% shorter than that of Non-Verbal Test BD.

¹ The test manual gives norms at six month intervals between the ages of 5:6 and 11:0, in terms of a percentile scale having raw score equivalents at the 5, 10, 25, 50, 75, 90, and 95% points. In order to interpolate ages and percentiles not given in the table, a graph was constructed showing chronological age plotted against raw score for each percentile tabulated. Percentiles obtained from the graph were converted to standardized scores, thus permitting a direct comparison with the standardized score obtained on the reading test.

As was mentioned above, the 7+ survey provided data on the verbal ability and reading attainment of first year Junior school-children, and it was originally thought that this information could be supplemented by just one further test, viz., Coloured Progressive Matrices. However, the screening of second year children, which took place before that of first year children, very quickly revealed a considerable degree of inaccuracy in the norms of this test, their scores being, on average, some 20 points higher than those obtained on the English Picture Vocabulary Test. As a result, a child who was selected for individual testing on the basis of the disparity between his EPVT score and his Reading Test AD score almost invariably met the criterion when his CPM score and Reading Test score were compared. So, despite the fact that it measured the same kind of abilities as the Non-Readers' Intelligence Test, the EPVT appeared to be the better choice for the supplementary test given to first year children, since it would lead to the selection of most children who would have been selected through CPM and avoid the selection of some children who were not genuinely retarded in reading.

Table 2.2 summarizes the characteristics of the tests used in Stage II of the screening process, the set taken by first year Junior children being shown separately from those taken by children in the second year and above. The Schonell Graded Word Spelling Test (SGWST), Form A, was given as a group test to children in the second year and above, and in most cases it was re-taken by children who proceeded to the following stage of individual tests, but spelling age was not one of the criteria used at any stage in the selection of retarded readers.

First year children, with the exception of two who will be noted in due course, were selected for individual testing (Stage III) if their

standardized score on the Group Reading Test (Young) was 24 points (i.e., 1.6 SD) or more below their score on either the Non-Readers' Intelligence Test or the EPVT 2.

Children in the second year and above, again with some exceptions mentioned below, were selected for individual testing if their score on Reading Test AD was 24 points or more below their score on either the EPVT or the CPM. Since performance on both the latter tests should be independent of the child's level of reading ability, (and the Non-Readers' Intelligence Test had been constructed with the same consideration in mind), it was not considered likely that the use of an additional criterion relating to the reading score alone (1.6 SD below the mean, say), would result in a significantly greater number of retarded readers being selected. In view of the fact that, in the IoW study, the incidence of reading backwardness had been found to be twice that of reading retardation, it was thought that the adoption of such a criterion, which does not distinguish between backwardness and retardation, would lead to the stage of individual testing being unnecessarily prolonged owing to the inclusion of poor readers who were not retarded in reading. It is true that in the aforementioned study this criterion had resulted in the identification of the largest number of retarded readers, but this number would probably have been reduced, and the number selected on the basis of their verbal IQ-reading score difference correspondingly increased, had performance on the verbal IQ test been less dependent on the child's reading ability. However, in planning the present screening procedure, there was some doubt as to whether the proposed criteria (i.e., the verbal IQ-reading score difference and the non-verbal IQ-reading score difference) would prove to be effective, since they had succeeded in

identifying only 17 of the 86 retarded readers in the IoW study. Accordingly, even though it was expected that the EPVT would be more efficacious in revealing the true dimension of children's verbal-reading disparities, the value of the criterion difference was reduced from 2 SD to 1.6 SD, a measure which it was thought would to some extent compensate for the reduced number of sources available, without adding significantly to the number of backward readers who might be selected.

The choice of 24 points of the standardized scale (or 1.6 SD) as the criterion difference was partly influenced by the outcome of the screening procedure at the first school visited. Amongst the fourth year children submitted by the teachers, one boy in particular was noted as coming within the category described. When the results of the group tests were examined it was found that both his verbal (EPVT) and non-verbal (CPM) scores were 23 points higher than his reading score. Another boy in this group obtained a similar overall result, his reading score falling 12 points below his verbal score and 32 points below his non-verbal score, but none of the remaining children were so markedly retarded. These two boys subsequently took the short form of the WISC and the Neale Analysis of Reading Ability, obtaining reading accuracy scores 28 and 31 months, respectively, below the predicted level. It was concluded that relaxation of the inter-test criterion from 2 SD to 1.6 SD would prevent rejection of a proportion of children who would meet the main criterion of retardation at the individual test stage. Accordingly, the criterion difference at the group test stage was set at 24 points. It was later found that even lower inter-test differences were obtained by children who nevertheless met the main criterion.

Children satisfying the inter-test criterion of Stage II were next approached with a view to their executing, in the first instance, four individual tests designed to give a more reliable picture of their intellectual abilities and attainment in reading and spelling. The tests at Stage III comprised a short form of the Wechsler Intelligence Scale for Children, The Neale Analysis of Reading Ability, Form B, The Schonell Word Spelling Test, Form A, and a word reading/spelling test based on a procedure devised by Eoder (1973). Children had already performed the Schonell Grade Word Spelling Test at Stage II, but they were re-tested in the course of the individual tests as it is difficult to determine, when it is undertaken by a group, whether every child has reached the limit of his capabilities.

In formulating multiple regression equations for the prediction of reading ability in IoW 9- to 11-year-olds, Yule (1967) used a short form of the WISC based on the work of Maxwell (1959) and comprising four subtests: Vocabulary, Similarities, Block Design, and Object Assembly. The application of these equations to further cases obviously demands that the same measure of intelligence be employed. The two relatively independent scores which can be obtained from these four subtests also provide a more systematic basis for matching children's cognitive abilities than can be obtained by the use of either Verbal, Performance, or Full Scale IQs, and they were adopted to this end in forming the control groups of normal readers, as will be described later in this section. Henceforth the sum of the Vocabulary and Similarities subtest scores will be referred to as the Maxwell Verbal Score (MVS), and the sum of the Block Design and Object Assembly subtest scores will be designated the Maxwell Performance Score (MPS).

The criterion for selection as a retarded reader was exactly as formulated by Rutter et al., namely a measured reading age which, in terms of either accuracy or comprehension, was 28 months or more below the level predicted on the basis of the child's CA and short form WISC IQ. Since Yule's prediction equations were derived for a sample of children aged 9 and 10 years, they may only be applied to children who come in the same age range. Insofar as the present study is concerned it was possible to employ the equations for all third and fourth year children and about half of the second year children, but for those in the first and second year who fell outside the range of the equations a different criterion had to be found. Consideration was first of all given to the feasibility of deriving a second set of equations for the age range 7 to 8 years, but enquiries failed to locate a suitable body of data furnishing WISC and Neale Analysis scores for a representative sample of children. It was therefore necessary to resort to the Achievement Quotient (AQ) measure. The degree of retardation represented by a particular value of the AQ depends on the age and IQ of the child, and it is consequently inappropriate to adopt a fixed value for the selection criterion. What was done, therefore, was to use the range of Quotients obtained by the groups of older retarded readers as a yardstick for the evaluation of younger children's performance. In making this estimation the following two considerations were borne in mind: (1) for AQs less than 100%, a given figure found in, say, an 8-year-old of average intelligence represents a slightly severer degree of retardation than the same figure obtained by an equally intelligent 10-year-old, and (2) for a low IQ child a given AQ represents a much severer degree of retardation than the same quotient obtained by a high IQ child of the same age.

The screening procedure was carried out with the aim of forming three groups, each comprising about ten retarded readers drawn from the age ranges 7-8 years (Group I), 8-9 years (Group II), and 9-11 years (Group III) (corresponding to the first, second, and third/fourth years of the Junior school), and in addition to recruit a matched control group in each age range. At the time the study was being planned it was thought inappropriate to include children of Infant school age though, with the benefit of hindsight, it might have been expedient to do so. Three main considerations governed this decision. (a) The practical difficulties associated with conducting group tests with very young children, and the poor reliability of their scores. (b) At the Infant school level there appears to be a great deal of variation between schools in the amount of time and effort devoted to reading and writing, and the same applies to different children within the same school. As a result, an appreciable proportion (estimates vary between 10% and 40%) of children in the last term of infant school and the first term of Junior school have hardly made a start with reading and spelling (Department of Education and Science, 1975). It would obviously be a mistake to conclude that all these children have specific learning disabilities. Unfortunately, it is not possible to predict with any degree of accuracy which of them will continue underachieving and which will master reading and writing skills within a reasonably short period. In other words, it is difficult, before the age of seven years, to distinguish a child who is a late developer from one who will have a persistent learning difficulty. (c) Lastly, it was thought that the test program itself, stretching over several months, would prove too arduous for young children.

In selecting the control groups it was thought desirable to employ a method involving direct control of factors associated with reading ability, since to allow for them statistically would call for more complex and protracted computational procedures. As noted previously, intelligence is quite highly-correlated with reading skill, at least in children older than 7 or 8 years. Since the multiple regression equations used to calculate children's predicted reading ages take account of the correlation between IQ and reading ability, then it can be safely assumed that the disparity between the retarded reader's measured and predicted reading ages is not associated with a lack of intelligence. Nevertheless, it is still necessary to match the intelligence of the control subjects with that of the retarded readers, to avoid the two factors being confounded, if only in part.

The association between the child's level of reading ability and the parents' social class has been noted in a number of studies. The results of the National Child Development Study (Davie, Butler, and Goldstein, 1972), a longitudinal survey of a national sample of children, showed that, in terms of reading age as measured by the Southgate Reading Test, 7-year-olds whose fathers were in non-manual occupations were on average about 11 months ahead of those from social classes IIIM and IV, and about 15 months ahead of those from social class V, after all other factors under investigation had been allowed for. By the age of 11 years children from non-manual backgrounds were 23 months ahead of those from social classes IIIM and IV, and 36 months ahead of those from social class V (Fogelman and Goldstein, 1976).

In the same longitudinal study it was also found that reading ability was strongly associated both with the number of older children

in the family and the number of younger children. For example, at 7 years of age the mean difference in reading age between those who were the eldest in the family and those who had three or more older siblings was about 16 months in favour of the former, while the difference between those without any younger siblings and those with three or more was 10 months. At 11 years of age the difference between those who had no older siblings when aged 7 and those who had three or more was 22 months, and the corresponding difference in respect of younger siblings was 19 months. There was some doubt as to whether it would prove feasible to match both the number of older and the number of younger siblings, because when one of the factors controlled is the school attended by the retarded reader the number of potential candidates for the control group is limited. Given that the effects relating to the numbers of younger and older children are of the same order of magnitude, a composite measure, viz., size of family, should afford a reasonable approximation to these two factors. It was expected that any matching errors introduced by the failure to take proper account of birth order would balance each other out when taken over a number of children.

In the National Child Development Study several other factors were reported to be associated with reading ability, but the effects were less pronounced than those arising from social class and family size differences, and the only one that need be considered here is the sex of the child. At the age of seven years, girls were found to be just over six months in advance of boys, but by the age of eleven there were no overall sex differences. However, it is known from other studies that reading retardation occurs much more frequently in boys than in girls, most estimates of the male/female ratio being in the range of

3:1 to 6:1 (Critchley, 1970; Naidoo, 1972; Rutter, Tizard and Whitmore, 1970). The present study is not concerned with exploring the reasons for the sex difference in reading retardation, and early in the recruitment phase a decision was made to restrict the composition of the sample to boys.

The length of the child's schooling was taken into account only insofar as children in the control groups were selected from the same school year as the retarded readers, without any allowance being made either for the time spent in the infant school (which can vary between two and three years) or for attendance at a nursery school or play-group. However, information on these matters was obtained in the course of the study.

With regard to the school itself, there is evidence (Morris, 1966; Department of Education and Science, 1975) that several of its characteristics have an important influence on the general level of attainment in reading and spelling. Morris, whose study was based on a random sample of 60 Kent primary schools, reported that the average reading ability of 7- to 11-year-old children from larger schools was significantly higher than that of children in smaller schools, and also that urban schools achieved significantly better results than rural schools, the latter result being partly a consequence of the urban vs. rural distribution of school size. It was also found that the level of achievement of children in the second, third, and fourth years of separate Junior schools was higher than that of children in the same years of Junior with Infant schools, though it was not established whether this was a direct effect of the form of organization or whether the difference was mediated by other factors associated with the two

types of school. Furthermore, when school and classroom conditions were examined it was found, not surprisingly, that the better the accommodation and facilities, the higher were the standards of reading. The group of Cambridgeshire schools taking part in the present study is relatively homogeneous in respect of the characteristics considered, but it was nevertheless considered desirable to ensure as far as possible that each child who served as a control subject came from the same school as the retarded reader with whom he was matched.

Thus, in order to form the control groups matching was undertaken on an individual basis with the aim of recruiting boys of average or above average reading ability who satisfied the following additional criteria:

- | | | |
|--|---|--|
| (1) Maxwell Verbal Score of normal reader | = | Maxwell Verbal Score of retarded reader +/- 1. |
| (2) Maxwell Performance Score of normal reader | = | Maxwell Performance Score of retarded reader +/- 1. |
| (3) Social Class of normal reader's family (in terms of father's occupation) | = | Social Class of retarded reader's family, within one Class of Registrar-General's Classification of Occupations. |
| (4) Size of normal reader's family | = | Size of retarded reader's family +/- 1 child |
| (5) Stage of schooling of normal reader | = | Stage of schooling of retarded reader |
| (6) School attended by normal reader at beginning of study | = | School attended by retarded reader at beginning of study |

No attempt was made to ensure that children's chronological ages were more closely matched than was required by criterion (5), for although the effective tolerance was about 12 months, it was thought that the resulting mis-matches would balance each other out in such a way that the mean ages of the two groups should be more or less in agreement.

In carrying out the recruitment of normal readers it soon became

apparent that there were some instances where it was not possible to find a single individual who satisfied both (1) and (2) above. In these cases it was necessary to recruit two normal readers, both satisfying criteria (3) - (6), but one having the same Maxwell Verbal Score and the other the same Maxwell Performance Score as the retarded reader. In this way two control groups were effectively formed, one of which served as the control in experiments involving verbal tasks, and the other performing the same function in respect of experiments involving non-verbal tasks.

The children taking part in the study were drawn from nine local authority primary schools and two village colleges situated either in the City of Cambridge or in towns and villages within a twenty-mile radius. Some of the characteristics of the school and its locale which are known to influence the overall level of pupils' attainment in reading have already been mentioned, but for the purposes of this study it was neither desirable nor practicable to ensure that the sample of schools was strictly representative of those in the area. Of the eleven schools visited, three were located in the City of Cambridge, one in the City of Ely, and the remaining seven in villages within 10 miles of Cambridge. Six of the nine primary schools were modern (post-war) buildings and one was built in the last century, while the remaining two had split sites with an old building housing part of the school (the lower school in one case and the upper school in the other) and a modern building housing the remainder. Three schools had Junior pupils only, and six had both Infant and Junior departments, a distribution similar to that found in the country as a whole. In all the primary schools, with one exception, children were grouped in classes according

to their year of birth. One of the Junior with Infant schools organized its classes in vertical groups, with a horizontal boundary between Infant and Junior departments, except that during the study the Junior system was modified by the introduction of a separate class for fourth year pupils.

One of the considerations governing the choice of schools, having in mind the need to make the most economical use of the time available, was that they should be fairly large, so that the number which it would be necessary to visit would be kept to a minimum. Also, it was thought that by choosing larger schools the task of selecting good readers for the control groups would be made easier, considering that one of the factors on which the groups were matched was the school attended. Thus, of the primary schools selected, eight had between 350 and 500 pupils on roll, and one had 280 pupils. That the sample is not typical in respect of size may be judged from the fact that the average number of pupils in an English primary school is 230, and only about 20% of primary schools have more than 350 pupils. One would expect, in view of the findings from studies such as those by Morris (1966) and Davie, Butler, and Goldstein (1972), that in a sample composed predominantly of larger schools the average level of attainment would be significantly higher than that found in smaller schools in the same region, other factors being equal.

Recruitment of retarded readers was confined to the primary schools, but a few of the fourth year Junior retarded readers left the Junior school before suitable children for the control group had been found, so that it was necessary to take up the search for normal readers in the colleges to which the retarded readers had moved. Two village

colleges were involved in the study, one of which was housed in a modern building with about 700 pupils on roll, and the other being an older building with extensive modern additions and about 1100 pupils on roll.

Having identified those children whose group test results qualified them for Stage III, whether as a potential member of the retarded readers' group, or the control group, their parents' co-operation was sought in two stages by means of a letter accompanied by a form for their reply. The first letter included a statement of the aims of the study, informed the parents of the group tests which had been given and, in the case of the retarded readers, advised that the child's reading level did not appear to be as advanced as might have been expected in the light of his general intellectual ability. It was pointed out that group tests do not always give reliable results, and permission was sought for the child's participation in two sessions of individual tests, the aim of which was to obtain a clearer picture of his intellectual abilities and attainment in reading and spelling. It was also explained to parents that, depending on the results of these preliminary tests, the child's participation in further tests might be sought but that there was no obligation to continue. The parents were subsequently advised by letter of the outcome of the Stage III tests, and if the child had met the selection criteria his participation in the next phase of the study was requested.

The initial letter to the parents of children who were selected as possible candidates for the control groups was along similar lines to that which was sent to the retarded readers' parents, except of course that there was no reference to reading difficulties (though in one or two instances this assessment had to be revised in the light of the outcome of the Stage III tests), the study being described in general

terms as one concerned with children's reading and spelling.

The parents of 195 children (46 potential candidates for the retarded readers' groups, and 149 potential members of the control groups) were approached in connection with the Stage III tests, and permission was granted in the case of all but four of the retarded readers and all but 13 of the normal readers. Of the 33 boys found to be retarded in reading, 32 (including 5 who were recruited through the control group selection process) were able to carry out the test program. Two good readers who, following the Stage III tests, were invited to join the control group declined to do so, and substitutes had to be found for them. The full test program was eventually completed by all 82 participants.

In order to maximize the differences between the mean ages of children in the three Groups the original intention was to arrange for the screening of Groups I, II, and III to take place in the first, second, and third terms, respectively, of the academic year. However, the head teacher of the first school to be approached in connection with first year screening pointed out that this age group would be taking the 7+ survey tests during the Autumn term, and in view of the fact that it was their first experience of this kind, he considered it unwise to burden them with further tests. This advice was accepted and rather than approach other schools with a view to first year screening the schedule was revised, Group II screening being carried out in the Autumn term instead, and Group I screening being postponed until the Spring term, by which time the results of the county-wide 7+ survey were available. Group III screening took place as planned in the Summer term.

Screening began in the Summer term of 1974. Tests were given to Group III children in two schools, and as a result three third year and

two fourth year boys retarded in reading were identified, who subsequently agreed to participate in the study. A third school was visited with the intention of recruiting Group III children, but the outcome of the consultation with teachers was that there were no children with severe reading difficulties in that age range. (It may be noted in passing that the headmistress of this school regularly heard children read and personally kept records of the reading progress of every child in the school, a degree of organization on the part of a head teacher not encountered at any of the other eight primary schools visited.) There was not sufficient time in the Summer term either to visit a fourth school or to select normal readers for the control groups at the schools where the retarded readers had been identified. What remained to be done in respect of Group III recruitment was therefore left until the Summer term 1975.

Three Group II schools were visited in the Autumn term of 1974, and 11 retarded readers were recruited by May 1975 (the majority were recruited by the end of the Autumn term 1974, but two other retarded readers were identified during the course of screening normal readers). The Group II control group was completed by June 1975. In the meantime screening of Group I retarded readers had taken place at three schools during the Spring term. Because Stage III individual tests and the test program itself were by that time being taken by a number of Group II and Group III children, the Group I recruitment process became relatively protracted, so that the retarded reader group was not completed until October 1975, while the matched control group did not reach its full complement until February 1976, by which time its members were in the second term of their second year. But before this point was reached, in

the Summer term of 1975, the uncompleted task of Group III recruitment had been taken up at the two schools which had been visited a year earlier, and also at a third school. At the former two schools screening of normal readers was carried out in order to find control subjects who matched the five retarded readers recruited the previous year, though by the end of the term the process was still not complete. At the school where fourth year recruits were being sought only one control subject was found before the term ended, and it was necessary to carry out further screening at the Village College, the group taking part being comprised of 1st year boys who had come from several primary schools in the catchment area. With regard to the other primary school which had been visited the previous year, recruitment of control subjects continued into the fourth year and was completed by February 1976.

At the school visited for the first time in the Summer term of 1975 a further five retarded readers, drawn from both the third and fourth years, were identified. It was necessary to return to the same school in the Autumn term to seek control subjects for the third-year boys (by now in the fourth year), and control group recruitment also had to be extended to the first year of the Village College (not the same College referred to previously), to which the fourth year Junior retarded readers had moved in September 1976. This phase of Group III recruitment was not completed until June 1976, being prolonged on account of the fact that the test program was already under way with those who had been recruited. Thus, the complete recruitment phase extended over a period of almost 2 years, with a considerable portion of this period also being devoted to the test program proper.

Table 2.3 gives a school by school synopsis of the numbers of children involved in the three stages of the screening procedure for the retarded reader groups, and Table 2.4 gives the same information for the control groups. It may be noted that two retarded readers recruited to Group I and three recruited to Group II were selected through the control group screening procedure.

The revision that was made in the original schedule, coupled with the fact that the recruitment phase for Group I subjects was longer than that for Group II, resulted in two groups whose mean ages, at the time their members commenced the test program, differed by only a matter of months, instead of the full year that had been envisaged. For the purposes of some of the analyses to be described in later chapters it will therefore be convenient to merge the results obtained by Groups I and II.

Table 2.5 shows the range, mean, and SD of the inter-test differences obtained by the retarded readers (RR), the normal readers (verbal control), (NR(VC)), and the normal readers (non-verbal control), (NR(PC)), in each of the three age ranges. It can be seen that not all the retarded readers' inter-test differences were greater than 24 points, and though the overall pattern of results would not necessarily have been inconsistent with each retarded reader obtaining a 24 point (or greater) difference on either one or other of the comparisons, there were cases where neither of the inter-test differences exceeded the criterion. In Group I there were two such exceptions. The first was a boy who was not amongst those referred by the class teachers (in terms of the 7+ survey tests the difference between his IQ and reading score was only 8 points) but who was later brought to the author's attention

Table 2.3 Synopsis of recruiting process - retarded reader groups

	Group I Schools			Group II Schools			Group III Schools			Total
	A	B	C	D	E	F	G	H	I	
No. on roll	420	354	415	500	280	500	365	357	470	3661
No. of children in relevant year:										
First	63	47	70							180
Second				125	69	80				274
Third							108	78		186
Fourth								92	65	157
No. of boys taking Stage II tests:										
NRIT (Young)	33	24	36							93
GRT (Young)	33	24	36							93
EPVT	11	10	8	10	12	7	11	11	7	87
CPM				10	12	7	11	11	7	58
NFER AD	1		1	10	12	7	11	11	7	60
GWST (Schonell)				10	12	7	11	11	7	58
No. of boys taking Stage III tests	4	6	5	8	4	2	5	6 ¹	2	42
No. of boys retarded in reading	2	5	3	5	2	1	3	5	2	28
No. of retarded readers recruited to test program	2	5	2 ²	5	2 ³	1 ⁴	3	5	2	27
No. of potential retarded readers (Stage II) recruited to control group	3	1	1	0	0	1 ⁵	0	0	0	6
No. of potential retarded readers (Stage III) recruited to control group	1	0	1	0	0	1	0	0	0	3

Notes:

- ¹ One boy in this group completed the first session of Stage III tests, but did not wish to continue.
- ² A third boy found to be retarded in reading moved from the area soon after completing the Stage III tests.
- ³ One of these two boys completed the test program but was dropped from the group at the data analysis stage, as his difficulties were thought to be primarily attributable to low intellectual ability and lack of motivation.
- ⁴ This boy completed the test program but was dropped from the group at the data analysis stage, as the degree of his retardation was not severe.
- ⁵ This boy served as the MPS control subject for the boy referred to in Note 4.

Table 2.4 Synopsis of recruiting process - control groups

	Group I Schools			Group II Schools				Group III Schools				Total
	A	B	C	D	E	F	G	H	I	J	K	
No. on roll	420	354	415	500	280	500	365	357	470	717	1119	5497
No. of children in relevant year:												
Primary												
First	63	47	70									180
Second				125	69	80						274
Third							108	78				186
Fourth								92	65			157
Secondary												
First										193	252	445
No. of boys taking Stage II tests:												
NRIT (Young)	33	24	36									93
GRT (Young)	33	24	36									93
EPVT	16	14	12	26	12	13	33	21	17	17	22	203
CFM				23	12	13	33	25 ²	17	17	22	162
NFER AD	8	4	4 ¹	26	9	7	33	26 ²	17	17	22	173
GWST (Schonell)							33	20	17	17		87
No. of boys taking Stage III tests	14 ³	12	9	21	10	7	13	22	5	11	12	136
No. of potential control subjects declining to take part in test program	1	0 ⁴	0	0	0	0	0	1	0	0	0	2
No. of retarded readers recruited from control group screening	2	0	0 ⁵	2 ⁶	0	1	0	0	0	0	0	5

Notes:

- ¹ In addition, nine boys at this school took the Southgate Group Reading Test, Test 1 (Form A).
- ² Three members of this group took NFER Reading Test BD, instead of Reading Test AD.
- ³ Two members of the control group were members of the potential retarded reader group (Stage II), and one member of the control group was a member of the potential retarded reader group (Stage III).
- ⁴ One of the potential control subjects moved to an independent school soon after completing the Stage III tests, and a substitute was found at another school (C).
- ⁵ One boy would have qualified for the retarded reader group but no approach was made to recruit him.
- ⁶ A third boy met the criterion for retardation, but the class teacher would not permit him to be defined as such.

Table 2.5 Stage II group tests: inter-test differences obtained
by retarded and normal readers

Age Range	Group	Tests Compared	Inter-Test Difference			
			Range From	To	Mean	SD
Group I	RR	NRIT-GRT	8	39	20.09	9.86
		EPVT-GRT	13	40	26.73	7.60
	NR(VC)	NRIT-GRT	-5	32	13.50	11.53
		EPVT-GRT	-12	28	7.27	11.33
	NR(PC)	NRIT-GRT	-10	32	16.30	12.83
		EPVT-GRT	-12	28	6.45	11.65
Group II	RR	EPVT-NFER AD	7	27	17.11	7.22
		CPM-NFER AD	18	56	38.67	11.58
	NR(VC)	EPVT-NFER AD	-25	6	-4.25	10.17
		CPM-NFER AD	-31	32	13.25	19.50
	NR(PC)	EPVT-NFER AD	-25	6	-5.63	11.82
		CPM-NFER AD	-9	32	15.00	13.15
Group III	RR	EPVT-NFER AD	12	38	20.40	8.37
		CPM-NFER AD	17	44	27.50	7.60
	NR(VC)	EPVT-NFER AD	-20	11	-0.10	8.95
		CPM-NFER AD	-31	22	-3.10	18.87
	NR(PC)	EPVT-NFER AD	-23	13	-4.70	9.67
		CPM-NFER AD	-7	24	4.33	11.03

by the head teacher. He had obtained a score of 88 on the Group Reading Test of the 7+ survey, but when tested at the age of 8:4 on NFER Reading Test AD he was unable to do the first two questions without help, indicating that his standardized score was below 76. The latter score was 28 points below his EPVT score, a difference which was large enough to qualify him for the Stage III tests. The second boy in Group I who did not qualify in terms of either his NRIT-GRT disparity (8 points) or his EPVT-GRT disparity (13 points) was, like the first, not a member of the group originally referred by class teachers. In fact, he was considered as a potential member of the good readers control group, and he reached the stage of individual tests before the severity of his retardation was recognized.

In Group II, one boy who took part in the control group screening obtained an EPVT-NFER AD disparity of 19 points and a CPM-NFER AD disparity of 18 points. As several boys with lower verbal-reading differences than his (though with higher non-verbal-reading differences) had been selected for the retarded reader groups, his participation in the Stage III tests was requested, with the result that he was found to meet the criterion.

In Group III, two boys obtained Stage II inter-test differences which were somewhat short of the criterion (their EPVT-NFER AD disparities being 14 and 20, respectively, and their EPVT-CPM disparities being 22 and 17), but they were, nevertheless, asked to take part in the Stage III tests. It was found that they both met the reading retardation criterion by a margin of more than 6 months.

There were also some exceptions, in an inverse sense, amongst the control group subjects. Thus in Group I, two boys who had been described

as poor readers by their class teachers and had also obtained inter-test differences greater than 24 in respect of both the NRIT-GRT comparison and the EPVT-GRT comparison, nevertheless achieved reasonably satisfactory results on the individual tests. In Group II, two boys who were selected for the control group screening obtained CPM-NFER AD differences greater than 24, a result which in these instances probably reflected the inaccuracy of the CPM norms (they both obtained scores of 135), rather than a genuine degree of under-achievement.

Table 2.6 shows the mean and SD of the standardized scores (SS) obtained on Stage II tests by the retarded and normal readers in each of the three age ranges. With two exceptions noted in the table there were no significant differences in terms of these group test scores between either the verbal or non-verbal abilities of the retarded readers and the normal readers. The two exceptions both occurred in relation to the performance of Group I children on the Non-Readers Intelligence Test, where the mean scores of the Verbal and Performance IQ control groups exceeded that of the retarded reader group by 9 points and 11 points, respectively. However, the verbal difference in favour of the normal readers yielded by the NRIT is not reflected in the EPVT scores, where the differences, though not as large, are in the opposite direction, a result which suggests that the NRIT may not be as suited to the evaluation of poor readers' verbal abilities as the author of the test claims.

Table 2.7 summarizes the results obtained by the retarded and normal readers on the Stage III individual tests. As was found at Stage II, there were no significant differences either between the verbal (MVS) scores of the retarded readers and normal readers, or between their

Table 2.6 Stage II group tests: performance of retarded and normal readers (in terms of mean and SD of SS).

Age Range	Test	RR		NR(VC)		NR(PC)	
		Mean	SD	Mean	SD	Mean	SD
Group I (N = 11)	NRIT	101.82	11.75	111.30*	9.91	113.40*	10.64
	EPVT	108.45	7.15	105.27	10.21	103.82	12.38
	GRT	81.73	7.34	98.00**	9.28	97.36**	10.49
Group II (N = 9)	EPVT	101.89	8.42	101.38	12.20	101.89	13.23
	CPM	123.44	14.37	118.88	24.14	122.56	15.27
	NFER AD	84.78	8.26	105.63**	7.94	105.75**	6.23
Group III (N = 10)	EPVT	101.00	12.71	103.60	11.85	106.30	19.10
	CPM	108.10	9.65	100.60	20.41	113.67	11.59
	NFER AD	80.60	9.26	103.70**	15.17	111.00**	12.37

* Difference from RR score significant at 5% level (t-test with paired observations)

** Difference from RR score significant at .1% level (t-test with paired observation)

Table 2.7 State III individual tests: performance of retarded and normal reader groups (in terms of mean and SD of scores).

Measure		RR		NR(VC)		NR(PC)	
		Mean	SD	Mean	SD	Mean	SD
Group I							
CA	(mo.)	100.91	3.45	103.09	3.96	104.09	4.76
MVS	(SS)	28.09	3.42	28.73	2.61	29.09	2.81
MPS	(SS)	26.55	5.24	26.00	6.26	26.09	5.97
RA (Acc)	(mo.)	88.27	7.21	111.09**	7.65	111.91**	8.87
RA (Comp)	(mo.)	92.91	10.97	115.27**	12.43	119.18**	14.80
SA	(mo.)	80.45	5.77	104.45**	9.27	103.64**	7.83
P(Cam)-M RA(Acc)	(mo.)	17.36	5.94	-2.09	8.12	-1.09	7.26
P(Cam)-M RA(Comp)	(mo.)	19.18	8.05	1.09	8.63	-0.36	12.18
AQ	(%)	76.19	3.25	91.51**	7.31	92.44**	6.81
Group II							
CA	(mo.)	109.00	3.71	108.78	4.21	110.11	3.55
MVS	(SS)	27.89	4.11	28.11	2.93	28.67	3.08
MPS	(SS)	27.00	4.97	25.56	5.27	26.78	4.82
RA (Acc)	(mo.)	95.11	7.25	124.33**	7.68	128.56**	11.80
RA (Comp)	(mo.)	102.22	10.54	134.67**	11.34	135.22**	12.63
SA	(mo.)	88.11	7.59	114.33**	6.52	118.00**	14.20
P(Cam)-M RA(Acc)	(mo.)	22.33	5.02	-8.22	7.21	-9.00	7.38
P(Cam)-M RA(Comp)	(mo.)	25.56	8.82	-8.89	9.09	-4.56	6.69
AQ	(%)	75.31	4.13	97.88**	9.69	98.03**	6.45
Group III							
CA	(mo.)	131.50	3.31	134.50	10.80	134.60	10.35
MVS	(SS)	25.30	4.24	25.60	3.72	25.80	2.70
MPS	(SS)	26.60	4.48	23.50	5.32	27.00	4.59
RA (Acc)	(mo.)	96.80	11.62	135.80**	12.00	137.30**	14.62
RA (Comp)	(mo.)	108.70	18.74	140.50**	15.16	141.30**	16.03
SA	(mo.)	85.11	15.41	131.30**	13.17	137.40**	16.65
P(IoW)-M RA(Acc)	(mo.)	37.10	7.49	-2.40	10.56	-0.40	12.28
P(IoW)-M RA(Comp)	(mo.)	31.50	11.37	-1.20	12.02	2.40	11.31
P(Cam)-M RA(Acc)	(mo.)	32.20	7.96	-6.30	10.44	-5.10	12.28
P(Cam)-M RA(Comp)	(mo.)	29.50	12.78	-2.90	11.66	-0.30	11.14
AQ	(%)	68.92	4.87	92.82**	11.20	87.61**	10.78

** Difference from RR score significant at 0.1% level (t-test with paired observations).

non-verbal (MPS) scores. Close agreement on these measures had, of course, been the object of the matching procedure, although there were a number of instances where the tolerance of ± 1 standardized point was not met. Thus in Group I there was one case where the MVS of the normal reader was three points above the MVS of the corresponding retarded reader, two cases where the MVS of the normal reader was two points above the MVS of the corresponding retarded reader, and two cases where the MPS of the normal reader was two points below the MPS of the retarded reader. In Group II there was one case where the MVS of the normal reader was 5 points above the MVS of the corresponding retarded reader, and two cases where the MVS of the normal reader was 2 points below the MVS of the retarded reader. Lastly, in Group III there was one case where the MVS of the normal reader was 3 points above the MVS of the retarded reader, one case where it was 2 points above, and two cases where the MPS of the normal reader was 2 points above that of the retarded reader.

As outlined earlier in this section, the degree of reading retardation of all Group III boys and those in Group II over 9 years of age was determined by means of the multiple regression equations derived by Yule (1967) from the short WISC and Neale Analysis scores obtained by a randomly selected control group of 9- and 10-year olds taking part in the IoW study. (Although Rutter et al. generally refer to the children in this group as 9- and 10-year-olds, the actual age range of the sample appears to have been 9:2 - 11:2). The mean differences between the predicted and measured reading ages ($P(\text{IoW})-M \text{ RA}(\text{Acc})$, $P(\text{IoW})-M \text{ RA}(\text{Comp})$) are shown in Table 2.7 for Group III only, as the complete figures were not available for Group II (and not at all for Group I). One of the retarded readers and eight of the normal readers were beyond the upper

limit of the age range in which the equations can be legitimately applied. (The retarded reader was 3 months beyond the end of the range and the normal readers up to 13 months beyond.) Some degree of error would thereby be introduced into the values of their predicted reading ages, quite apart from that which was probably present through other conditions underlying the use of the equations being violated. In the case of the normal readers no great importance attaches to the accuracy of the predicted values in this particular application. However, the accuracy of the estimate is more important in the case of the retarded readers, though in the case referred to above the error would probably not have been greater than the margin (6 months) by which the difference between his predicted and observed reading ages exceeded the criterion. The figures given in Table 2.7 conceal the fact that Group III contained a boy whose observed Reading Age (Acc) was only 27 months below the predicted level, i.e. one month short of the criterion, but he was included in order to achieve the full complement and avoid extending recruitment to a further school.

In Group II the regression equations were applied in four cases where the ages of the boys ranged from 9:3 to 9:5, the 28 month criterion being met in all cases but one, where the measured Reading Age (Comp) was only 26 months below the predicted value. As the boy was near the lower end of the age range, it was thought that he could justifiably be included. In this regard, it would probably be more realistic when employing the multiple regression technique to adopt a criterion that varies as a function of chronological age, rather than a fixed cut-off point, particularly when the age range of interest is as broad as 2 years. Thus if the 28 month criterion were to be used for

children aged 10:2, the equivalent degree of retardation at 9:2 would be about 23 months and at 11:2 about 33 months.

The recruitment phase of the study yielded WISC and Neale Analysis data for quite a large sample of boys. There was no assurance at all that this sample was representative of the Cambridgeshire population of 8- to 11-year-olds, but since no other body of data was available for comparison with the IoW sample, it provided the only means of gauging the validity of employing the multiple regression equations derived by Yule. This body of data also allowed two sets of multiple regression equations to be computed for the age ranges 8-9 years and 10-11 years respectively. Further details of the distribution of IQ and reading ability in the Cambridgeshire sample, and the derivation of the regression equations are given in Appendix A. The multiple regression equations derived for the Cambridgeshire sample allowed the differences between predicted and measured reading ages ($P(\text{Cam})-M \text{ RA}(\text{Acc})$, $P(\text{Cam})-M \text{ RA}(\text{Comp})$) to be calculated for boys in all three groups, and the mean and SD of these scores are shown in Table 2.7. As a further check on the place of the present sample in the spectrum of reading retardation its characteristics were compared with those of a group of boys classed as dyslexic by psychologists at a private institute where assessment and teaching of children with this type of handicap is carried out. (See Appendix B).

The use of multiple regression equations may be illustrated by describing the results obtained by two Group III retarded readers, in relation to both the IoW and the Cambridgeshire sample. Taking the case of the first boy, the scores he obtained (at age 11:1) on the Neale Analysis and the short form of the WISC were as follows: $\text{RA}(\text{Acc}) = 9:0$,

RA (Comp) = 10:11, MVS = 31, MPS = 22. Thus, if CA = 133 and IQ = MVS + MPS = 53 are substituted in the second and third of the equations given in Table 2 of Yule (1967), the values that are obtained for his predicted RA (Acc) and RA (Comp) are 11:4 and 11:11 respectively. These values may be compared with those obtained for the same boy using the equations calculated for the Cambridgeshire 3rd and 4th year boys (see Table 2.8). Substituting the same values of CA and IQ as before, one obtains a predicted RA (Acc) of 11:0 and a predicted RA (Comp) of 11:9. Thus in relation to the Cambridgeshire sample this boy appears to be less retarded than he does in relation to the IoW sample, by a matter of 4 months in respect of Accuracy and 2 months in respect of Comprehension. However, in making this kind of comparison it is necessary to take into account the standard errors of estimate of the criterion variables, which are not the same in the two sets of equations. In order to do so the difference between predicted and measured values is converted to standard normal form by dividing by the standard error. Thus, in the case of the predictions based on the IoW equations:

$$Z_{Acc} = 28/15.74 = 1.78; \quad Z_{Comp} = 12/14.95 = 0.80,$$

while the same calculation for the predictions obtained from the Cambridgeshire equations yields the following result:

$$Z_{Acc} = 24/13.74 = 1.75; \quad Z_{Comp} = 10/13.19 = 0.76$$

If both samples had been randomly selected such close agreement between the two sets of normalized values could be taken to indicate that a 28 month difference between predicted and measured reading accuracy ages in the IoW sample is equivalent to a 24 month difference in the Cambridgeshire sample in the sense that the proportions of children in

Table 2.8 Multinle regression equations for prediction of reading
ages in Cambridgeshire Junior School boys

Measure	Regression Equation	Standard Error
First- and second-year boys		
RA (Acc) (mo.)	$-85.50 + (0.86 \times IQ) + (1.43 \times CA)$	11.49
RA (Comp) (mo.)	$-151.91 + (1.26 \times IQ) + (1.93 \times CA)$	13.54
Third- and fourth-year boys		
RA (Acc) (mo.)	$-8.71 + (0.69 \times IQ) + (0.78 \times CA)$	13.74
RA (Comp) (mo.)	$2.37 + (0.91 \times IQ) + (0.68 \times CA)$	13.19

the two samples who were under-achieving by these respective amounts, or more, are the same. However, it would probably be unwise to place a great deal of confidence in the values of the standard errors given for the Cambridgeshire equations as the sample on which they were based was definitely not a random one. One systematic bias in its composition arose from the fact that all its members were boys. Even so, one would not expect this restriction to have affected the mean of the reading score distribution, at least in the case of 10- and 11-year-olds, though it may have altered its shape at the extremes. More serious distortions in the distributions would probably have been introduced by virtue of the fact that no Independent schools or schools for the ESN were included, and also because the selection procedure was designed to exclude children with intellectual retardation or reading backwardness.

As a further example of the use of the multiple regression equations one might consider the case of a boy who was one of the most severely retarded members of Group III. He took the short form of the WISC and the Neale Analysis at the age of 10:8, obtaining the following scores: RA (Acc) = 6:3, RA (Comp) = 6:9, MVS = 21, MPS = 23. In terms of the IoW equations these figures give his predicted RA (Acc) and RA (Comp) as 10:4 and 10:8, respectively, while the corresponding estimates from the Cambridgeshire equations were 10:1 and 10:9, respectively.

In forming the control groups, two or more normal readers were seldom found whose social and intellectual characteristics matched those of a particular retarded reader, so that the question of which candidate to choose in these circumstances hardly ever arose. With regard to the level of reading ability, no specific criterion was

adopted in selecting members of the control groups, though in the great majority of cases the subject's reading age was in advance of his chronological age. However, there were reservations about a few of the control group members insofar as their reading ability, and more particularly their spelling ability, fell short of what was considered to be a satisfactory level.

In order to determine how representative of the general level of intellectual ability and achievement in reading and spelling the normal readers were, a comparison was made with the remaining boys who had performed Stage III tests but not been selected for the control groups. The comparison was made in respect of MVS, MPS, Reading Age (Acc), Reading Age (Comp), and Spelling Age, and was carried out separately for four groups: Group I, Group II, Group III (3rd year), and Group III (4th year), the Verbal and Performance control groups being merged within each age range. The comparison group of normal readers rejected at Stage III did not include any who had been found to be moderately retarded in reading, whether they had been recruited as potential members of the retarded reader groups and failed to meet the criterion, or whether they had originally been considered as candidates for the normal reader groups. The performance of the two groups is shown in Table 2.9, and it may be seen that the only significant difference occurs in respect of the Comprehension Age in Group I, where the performance of the normal readers not selected for the control group was superior to that of the control group itself.

Table 2.9 Reading ability and IQ of control group (VC and PC combined)
compared with that of normal readers not selected as controls

		Group I			
		NR(VC and PC)(N = 16)		NR(not VC/PC)(N = 19)	
Measure		Mean	SD	Mean	SD
CA	(mo.)	103.69	4.17	104.74	3.81
MVS	(SS)	29.00	2.48	29.37	2.85
MPS	(SS)	26.19	5.69	28.53	4.59
RA (Acc)	(mo.)	112.50	8.69	114.47	10.98
RA (Comp)	(mo.)	117.06	14.38	128.58*	14.96
SA	(mo.)	105.31	8.73	105.95	12.80
		Group II			
		NR(VC and PC)(N = 12)		NR(not VC/PC)(N = 19)	
Measure		Mean	SD	Mean	SD
CA	(mo.)	108.83	3.81	108.68	4.75
MVS	(SS)	28.33	3.14	27.37	3.88
MPS	(SS)	26.67	5.94	27.21	5.59
RA (Acc)	(mo.)	125.75	11.32	118.79	15.34
RA (Comp)	(mo.)	134.33	13.23	128.47	18.25
SA	(mo.)	116.83	12.39	111.17	13.22
		Group III (3rd year)			
		NR(VC and PC)(N = 7)		NR(not VC/PC)(N = 18)	
Measure		Mean	SD	Mean	SD
CA	(mo.)	125.29	5.44	128.72	3.39
MVS	(SS)	26.00	3.11	25.72	3.32
MPS	(SS)	25.29	4.54	22.39	5.75
RA (Acc)	(mo.)	126.29	16.55	128.39	12.26
RA (Comp)	(mo.)	135.57	18.41	136.72	11.36
SA	(mo.)	122.57	15.23	122.33	10.54
		Group III (4th year)			
		NR(VC and PC)(N = 10)		NR(not VC/PC)(N = 27)	
Measure		Mean	SD	Mean	SD
CA	(mo.)	140.10	5.78	141.70	4.63
MVS	(SS)	25.80	3.05	27.56	3.42
MPS	(SS)	24.50	5.87	25.56	5.67
RA (Acc)	(mo.)	142.10	5.95	139.15	8.34
RA (Comp)	(mo.)	143.40	14.07	148.63	6.57
SA	(mo.)	140.50	9.94	139.48	12.09

* Difference from control group (VC and PC combined) score significant at 5% level (t-test).

2.3 The intellectual, educational, and social characteristics of the retarded and normal readers

In this section the retarded reader and normal reader groups are described in terms of the factors which entered into the matching procedure. The verbal (MVS) and non-verbal (MFS) abilities of the groups, based on the short form of the WISC, have already been described (see Table 2.7). However, following Stage III all boys performed a number of other subtests from the WISC and their results will also be presented in this section, together with information on the educational background of the boys' parents.

The additional WISC subtests which were taken included Arithmetic and Digit Span from the Verbal Scale (Information and Comprehension being omitted) and Picture Completion, Picture Arrangement, and Coding from the Performance Scale (Mazes being omitted). As only four subtests from the Verbal Scale were used, it was necessary to prorate the sum of the scaled scores by $5/4$ in order to obtain the child's Verbal IQ. Two of the subtests, Digit Span and Mazes, are described in the test manual as being supplementary tests, and it is recommended that they normally be omitted, the former on account of its low correlation with other subtests of the Verbal Scale. However, Digit Span (but not Mazes) was purposely included, because scores on this test have been found to differentiate between poor readers and good readers. In fact it is evident from the results presented in Table 2.10 that Digit Span is the only subtest on which the retarded readers are consistently inferior to the normal readers across all three age ranges. It may also be noted from the Table that, whereas in Groups I and II retarded

Table 2.10 WISC subtest scores, Verbal IQ, Performance IQ, and Full Scale IQ for retarded reader and normal reader groups

Measure	RR		NR(VC)		NR(PC)	
	Mean	SD	Mean	SD	Mean	SD
Group I						
WISC						
Verbal Scale						
Arith.	11.09	2.43	11.91	1.87	10.64	1.69
Sim.	15.18	1.72	15.27	1.62	15.36	1.80
Vocab.	12.91	2.21	13.45	1.51	13.73	1.49
D.S.	9.18	2.32	11.00*	2.45	10.91	2.77
VIQ	113.18	7.93	118.27*	9.41	116.73	8.95
Perf. Scale						
P.C.	11.55	2.11	12.55	3.64	12.00	3.58
P.A.	11.45	1.86	12.00	3.49	11.64	3.98
B.D.	13.91	4.39	14.00	2.65	13.82	2.86
O.A.	12.64	2.11	12.00	4.12	12.27	3.66
Cod.	10.36	2.54	10.45	2.46	10.45	2.07
PIQ	113.82	9.28	115.36	16.43	114.27	14.77
FSIQ	114.82	7.77	118.45	12.46	116.91	11.47
Group II						
Verbal Scale						
Arith.	10.78	2.54	11.89	2.52	12.22	2.54
Sim.	15.44	1.81	15.44	1.74	15.67	1.66
Vocab.	12.44	2.46	12.67	1.32	13.00	1.66
D.S.	8.33	2.24	10.22	2.73	10.33	2.78
VIQ	111.00	9.82	115.89	9.79	117.44	10.10
Perf. Scale						
P.C.	11.89	2.26	11.67	3.28	12.11	2.42
P.A.	12.78	2.99	12.78	2.95	12.22	2.91
B.D.	12.89	2.98	13.44	3.54	13.67	3.84
O.A.	14.11	2.89	12.11	2.20	13.11	2.52
Cod.	11.89	1.90	11.89	2.42	12.11	2.85
PIQ	119.11	12.13	116.56	11.79	118.44	13.25
FSIQ	116.22	9.86	117.78	11.20	119.56	12.29
Group III						
Verbal Scale						
Arith.	8.30	2.11	10.90**	1.37	11.40***	1.35
Sim.	14.20	2.20	14.20	1.87	14.20	1.48
Vocab.	11.10	2.28	11.40	2.46	11.60	2.01
D.S.	7.70	2.26	9.90	3.41	12.40***	3.37
VIQ	102.20	12.59	109.90*	9.78	115.10**	8.47
Perf. Scale						
P.C.	11.30	3.02	11.50	4.33	11.00	4.19
P.A.	11.10	1.97	10.50	2.07	12.20	3.29
B.D.	12.90	2.88	12.00	3.92	13.40	3.66
O.A.	13.70	2.06	11.50	2.27	13.60	2.01
Cod.	8.60	2.68	10.40	3.41	11.60*	4.48
PIQ	110.50	9.13	108.20	15.17	116.50	16.42
FSIQ	106.80	10.52	109.90	11.33	117.20**	10.15

* Difference from RR score significant at 5% level (t-test, paired obs.)
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readers and normal readers are fairly evenly matched in their performance on the Arithmetic and Coding subtests, the same is not true of Group III, where the mean scores of the retarded readers are lower than those of the normal readers. This pattern of results suggests that retarded readers' difficulties with Arithmetic and Coding may be secondary to their reading difficulty, rather than having their roots in the same cognitive deficiency.

Table 2.11 shows the numbers of children in each age range who attended a nursery or playgroup prior to joining the Infant school. Combining the data from the three age ranges and applying a χ^2 test of association it was found that the retarded readers did not differ significantly from either the Verbal control group ($\chi^2 = 0.43$, $df = 1$), or the Performance control group ($\chi^2 = 0.02$, $df = 1$).

The length of a child's Infant school career was generally an integral number of terms between 6 and 9. Children were therefore placed in one of four categories corresponding to the number of terms they had spent in the Infant school, as shown in Table 2.12. (One boy who had spent two years and one month at Infant school was placed in the 6 term category.) A χ^2 test of association showed that with Groups I-III combined, there were no significant differences either between the retarded readers and the Verbal control group ($\chi^2 = 1.52$, $df = 3$), or between the retarded readers and the Performance control group ($\chi^2 = 2.38$, $df = 3$).

In forming the two control groups there were a number of instances where a matching normal reader could not be found within the same school as the retarded reader, and the search had to be extended to other schools in the sample. In Group I, one member of the Verbal control group and

Table 2.11 Attendance at nursery school or playgroup by retarded reader and normal reader groups

	RR		NR(VC)		NR(PC)	
	(No.)	(%)	(No.)	(%)	(No.)	(%)
Attended Nursery School or Playgroup						
Group I (N = 11)	8*	80	6	55	7	64
Group II (N = 9)	3	33	6	67	6	67
Group III (N = 10)	6	60	2	20	5	50
All Groups	17	59	14	47	18	60

*Information was missing for one member of this group

Table 2.12 Length of Infant schooling: Numbers of retarded and normal readers completing six to nine terms

Terms	Group I			Group II			Group III			All Groups		
	RR	NR	NR	RR	NR	NR	RR	NR	NR	RR	NR	NR
	(No)	(VC)	(FC)	(No)	(VC)	(FC)	(No)	(VC)	(FC)	(No)	(VC)	(FC)
9	8	8	7	5	5	5	4	5	8	17	18	20
8	3	1	1	1	1	3	0	2	0	4	4	4
7	0	2	2	2	3	1	1	0	1	3	5	4
6	0	0	1	1	0	0	5	3	1	6	3	2

four members of the Performance control group were attending different schools from that of the retarded reader. Also, during the course of the study, three retarded readers changed schools. In two cases the new schools were ones participating in the study, and in the other case it was a local authority school not previously visited, though within reach of Cambridge, where the staff were willing for the boy to continue the test program. In addition, a member of the Performance control group moved to an Independent school in the area, but permission was also obtained for him to continue the test program. In Group II every normal reader attended the same school as the retarded reader with whom he was matched. In Group III, four members of the Verbal control group, two of whom also served as Performance controls, were recruited at the Village Colleges and had attended primary schools which were not amongst those in the sample; the same applied to two further members of the Performance control group who were not also Verbal controls. Another member of the Performance control group was attending a school which, though within the sample, was not the same as that attended by the retarded reader.

With regard to the stage of schooling which boys had reached at the time of recruitment, no boy in Group I or Group II had been moved up or down by a year in the course of his school career. However, in Group III one third-year retarded reader would have been in the fourth year had he not spent two years in the second year. (The two matching normal readers were both drawn from the third year.) Another boy in Group III, who served as a Verbal/Performance control, was in the second year age range but had been moved up to the third year.

Table 2.13 shows the numbers of older children (a) and numbers of younger children (b) in the families of the retarded reader group and

Table 2.13 Size of family in retarded reader and normal reader groups.(a) Number of older siblings

Number of sibs	Group I			Group II			Group III			All Groups		
	RR	NR	NR	RR	NR	NR	RR	NR	NR	RR	NR	NR
	(VC)	(PC)		(VC)	(PC)		(VC)	(PC)		(VC)	(PC)	
	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)
0	3	4	3	4	5	5	5	4	4	12	13	12
1	7	5	7	4	3	3	2	2	3	13	10	13
2	1	2	1	0	1	1	0	1	2	1	4	4
3+	0	0	0	1	0	0	3	3	1	4	3	1

(b) Number of younger siblings

Number of sibs	Group I			Group II			Group III			All Groups		
	RR	NR	NR	RR	NR	NR	RR	NR	NR	RR	NR	NR
	(VC)	(PC)		(VC)	(PC)		(VC)	(PC)		(VC)	(PC)	
	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)
0	6	4	4	4	2	3	4	4	2	14	10	9
1	4	6	4	5	7	6	5	5	8	14	18	18
2	1	1	3	0	0	0	1	1	0	2	2	3

the two control groups. In Group I, the number of children in the normal reader's family was, in each case, matched with the number of children in the retarded reader's family, +/- 1. In Group II, there was one case where there were four children in the retarded reader's family and two children in the families of both the Verbal control and the Performance control. In Group III, there was one instance where a retarded reader who was one of five children was matched with a Verbal control who was one of seven and a Performance control who was one of three. A χ^2 test of association carried out on the distributions of older children showed that there were no significant differences either between the retarded readers and the Verbal control group ($\chi^2 = 2.38$, $df = 3$), or between the retarded readers and the Performance control group ($\chi^2 = 3.60$, $df=3$). The same test performed on the distributions of younger children yielded a similar result in respect of both the Verbal control group ($\chi^2 = 1.16$, $df = 2$) and the Performance control group ($\chi^2 = 1.78$, $df = 2$).

Table 2.14 shows the distribution of social classes within the retarded reader group and the two control groups. The criterion for matching children with respect to social class (+/- one Class) was met in the great majority of cases, but there were the following exceptions:

Group I

RR from Class IV matched with NR(VC) from Class II

Group II

RR from Class IIIM matched with NR(VC) from Class V
 RR from Class IV matched with NR(VC) from Class II
 RR from Class IV matched with NR(PC) from Class II

Table 2.14 Distribution of social classes in retarded reader and normal reader groups.

Social Class	Group I			Group II			Group III			All Groups				East Anglia		
	RR (No)	NR (VC) (No)	NR (PC) (No)	RR (No)	NR (VC) (No)	NR (PC) (No)	RR (No)	NR (VC) (No)	NR (PC) (No)	RR (No)	(%)	NR (VC) (No)	(%)		NR (PC) (No)	(%)
I	1	1	1	1	1	1	1	1	1	3	10	3	10	3	10	4
II	3	3	4	2	4	4	3	1	1	8	27	8	27	9	31	20
IIIN	0	1	2	1	0	0	0	1	1	1	3	2	7	3	10	10
IIIM	6	4	2	3	1	3	3	5	3	12	40	10	33	8	27	36
IV	1	2	2	2	2	1	3	1	2	6	20	5	17	5	17	22
V	0	0	0	0	1	0	0	1	1	0	0	2	7	1	3	8

Group III

RR from Class II matched with NR(VC) from Class IIIM
 RR from Class II matched with NR(VC) from Class IV
 RR from Class IIIM matched with NR(VC) from Class V
 RR from Class IV matched with NR(VC) from Class IIIN
 RR from Class II matched with NR(PC) from Class IV (two cases)
 RR from Class IIIM matched with NR(PC) from Class V
 RR from Class IV matched with NR(PC) from Class IIIN.

In order to provide adequate numbers in each cell for a test of association between the distributions to be performed, Classes II and IIIN were merged, as were Classes IV and V. It was found that, with Groups I-III combined, there were no significant differences either between the retarded readers and the Verbal control group ($\chi^2 = 0.32$, $df = 3$), or between the retarded readers and the Performance control group ($\chi^2 = 1.22$, $df = 3$). Using a likelihood ratio test of association, again with Class II merged with IIIN and IV merged with V, the distribution of social classes within the retarded reader group was compared with that found in the population of East Anglia (Reid, 1977). The distributions were essentially similar ($\chi^2 = 3.16$, $df = 3$).

Finally, in order to assess the influence of the parents' education on levels of attainment in reading, six stages of education were defined as shown in Table 2.15, the first part of which deals with the mother's education and the second with the father's. Having combined the data from Groups I, II, and III, it was analyzed in two ways. First of all, the number of parents who had left school at the minimum leaving age was compared with the number who had stayed on beyond that age. A χ^2 test of association showed that there were no significant differences in this respect either between the mothers of the retarded readers and the mothers of the Verbal control group ($\chi^2 = 0.0$, $df = 1$), or between the mothers of the retarded readers and the mothers of the Performance

Table 2.15 Parental education and training

	Group I			Group II			Group III		
	RR	NR	NR	RR	NR	NR	RR	NR	NR
	(VC)	(VC)	(FC)	(VC)	(VC)	(FC)	(VC)	(VC)	(FC)
	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)	(No)
Mother's Education									
Level of Education/ Training:									
Left school at minimum school leaving age	10	9	7	7	5	4	7	9	8
Left school after minimum school leaving age	1	2	4	2	4	5	3	1	2
Gained 1 or more 'O' level passes	2	4	5	1	3	4	1	1	2
Gained 1 or more 'A' level passes	1	1	1	0	1	3	1	0	0
Gained degree qualification	0	1	1	0	0	0	1	0	0
Other post-secondary qualifications (academic or vocational)	3	3	5	1	0	0	1	2	4
Father's Education									
Level of Education/ Training:									
Left school at minimum school leaving age	8	6	6	5	5	5	6	7	8
Left school after minimum school leaving age	3	5	5	4	4	4	4	3	2
Gained 1 or more 'O' level passes	3	6	7	4	4	5	2	3	3
Gained 1 or more 'A' level passes	1	3	2	1	1	2	1	1	1
Gained degree qualification	1	3	2	1	0	1	1	1	1
Other post-secondary qualifications (academic or vocational)	8	3	6	1	3	4	3	4	5

control group ($\chi^2 = 1.72$, $df = 1$). A similar picture emerged when the fathers of the retarded readers were compared with the fathers of the Verbal control group ($\chi^2 = 0.0$, $df = 1$), and with the fathers of the Performance control group ($\chi^2 = 0.07$, $df = 1$). The data was also analyzed in terms of the number of parents who had obtained one or more 'O' level passes (or School Certificate in one or more subjects), compared with the number who had no academic qualifications. Comparing the mothers of retarded readers with those of the Verbal control group, the difference was not significant ($\chi^2 = 0.94$, $df = 1$), though when compared with the mothers of the Performance control group the difference approached, but did not reach, significance ($\chi^2 = 3.20$, $df = 1$, $0.1 > p > 0.05$). When the fathers of retarded readers were compared with those of the Verbal control group in respect of academic qualifications the difference was not significant ($\chi^2 = 0.65$, $df = 1$), and a similar result was obtained when they were compared with the fathers of the Performance control group ($\chi^2 = 1.74$, $df = 1$).

To summarize the recruitment phase of the study, 30 Junior school boys retarded in reading and spelling were selected by means of a three-stage screening procedure involving (1) teachers' evaluations of pupils' abilities, (2) a battery of group tests, and (3) a set of individual tests of intelligence and attainment in reading and spelling. This group, comprising 3.76% of the male population of the Junior schools taking part, achieved measured reading ages which, on average, fell between 17 months (at 8 years of age) and 32 months (at 11 years) below the level that would be expected for boys of the same age and IQ. In addition, two groups of normal readers (boys) were selected to serve as control subjects, one having the same verbal abilities as the retarded readers and the other the same non-verbal abilities. (These two groups had some

members in common.) Both groups were also matched to the retarded readers for school attended, length of schooling, size of family, social class, and level of parental education.

Chapter 3

3.1 Introduction

In Chapter 1 it was argued that the persistence of letter orientation errors beyond the age of 8 or 9 years might be due to the failure of the visual system to establish or maintain a frame of reference. Support for this explanation is provided by studies which have shown that reading retardation is associated with delays in the development of both euclidean (or axial) concepts and projective (or polar) concepts, such as left and right. Regarding the former aspect, Inhelder (1962) observed that children who were slow in acquiring the concepts of the horizontal and vertical, as evinced in their performance on water-level and plumb-line tasks (Piaget and Inhelder, 1956), were frequently retarded in reading. This observation was confirmed by Lovell, Shapton and Warren (1964) in a controlled study of "backward" and normal readers who were matched for non-verbal intelligence, social class, school, age (9:8), and sex. Moreover, certain types of error in symbol formation described in case studies appear to be a manifestation of immaturity in the conceptualization of space. For instance, Hermann (1959) reported the case of a child who wrote a hyphen as a vertical stroke (but then realized his mistake); he also observed a word-blind adult who wrote the mathematical symbol "=" as two vertical strokes. In another study, Goody and Reinhold (1961) commented on the frequent confusion by dyslexic children of the arithmetic symbols "+" and "x".

Case studies of retarded readers make frequent mention of difficulties in discriminating the left and right sides of the body (Shankweiler, 1964; Critchley, 1970), and there have also been a number of controlled studies (Harris, 1957; Hermann, 1959; Benton, 1959; Lovell, Shapton and Warren,

1964) which confirm that such readers differ significantly from normal in this respect. However, these findings are too general to be adduced as evidence for the hypothesis under investigation, and the purpose of the experiments reported in this chapter is to determine whether a delay in the development of spatial thought is specifically related to the occurrence of letter orientation errors. Before describing these experiments, a number of earlier studies will be reviewed in order to ascertain the expected incidence of orientation errors, though, as will be seen, the form in which these findings are presented is such that the basic parameters of the error distribution are frequently not apparent. Following this review, an analysis of spelling errors (including orientation errors) occurring in the Schonell Spelling Test is presented. The experiments concerning the conceptualization of euclidean and projective space are next described, and in conclusion, performance on the tests used to examine these concepts is related to the incidence of orientation errors in the Schonell Test.

Orton and Hermann both believed that the occurrence of letter reversals and inversions in the reading and spelling of dyslexic children is of fundamental aetiological significance insofar as it was viewed as one manifestation of a defect in visuo-spatial perception which is frequently of constitutional origin.

The first of Orton's (1925) studies described fifteen retarded readers (14 boys and 1 girl), aged from 6 to 16 years, who were amongst a group of 125 children referred to a clinic in Iowa by teachers and doctors on account of a variety of educational and behavioural problems. The Stanford-Binet IQs of the retarded readers ranged from 71 to 122, though further examination led Orton to the conclusion that the mental abilities of some boys with IQs in the lower part of the range were

appreciably higher than the figures indicated. Information about the children's reading ages was not given, but apparently there was considerable variation in the degree of retardation present, the most severe cases being two 16-year-olds who were virtually non-readers. While admitting that his test procedures were less than thorough, Orton maintained that there were four features common to all children in the group: (1) letter reversals in reading and writing (inversions occurred only rarely), (2) reversal of letter order, sometimes involving a complete syllable or word, (3) the ability to read mirror-reversed text with the same ease as normal text, and (4) the production of mirror writing (not all children did so spontaneously, and those who were asked to attempt it achieved varying degrees of success). The incidence of these four phenomena was not specified, though the first two were said to be "of constant occurrence".

In a more extensive study carried out in 1926-7, Orton (1937) compared 175 retarded readers referred to the same clinic with 120 normal readers, confirming the earlier finding that orientation and order errors (static and kinetic reversals, in Orton's terminology) are a prominent characteristic of reading disability:

"The two types (static reversals and kinetic reversals) are practically always to be found associated in any case of strephosymbolia, but they vary markedly both in their relative frequency and in the resistance which they offer to eradication by retraining. That the reversals play a significant role in strephosymbolia is adequately supported by our earlier studies in Iowa. The errors made by a group of reading disability cases were tabulated and compared with those made by a carefully selected control group of normal readers of the same reading grade and intelligence, and the errors by reversal were found to be significant statistically for the reading disability cases at each of the first four reading grades which were studied. Not only was this so, but the frequency with which errors by reversal appeared in the work of a given case proved to correlate with the amount of his retardation in reading, that is with the severity of his disorder." (p.151)

Unfortunately, Orton does not record the data on which his analysis and conclusions were based, so that it is impossible to determine the frequency of orientation and order errors produced by his sample.

Hermann (1959) described, in general terms, various types of error and their frequency of occurrence, and he presented numerous examples taken from case records, but the data were not presented in a systematic form. He maintains that: "A great many varied types of error can be found in congenital word-blindness, and some of these occur so frequently as to give the word-blind person's reading a special quality (for example, rotations and reversals¹)." (p.43). One of the cases cited by Hermann was of an intelligent 10-year-old girl who, in a passage of text containing four instances of the letter b and ten instances of the letter d, wrote d for b three times and b for d once. In one of the few analyses of group data which Hermann described, he reported, albeit incompletely, the results of a test in which 100 Danish children, aged 15 years old, read individual letters presented in random order. One of the letters which gave particular difficulty was q (which occurs infrequently in Danish). Of the 100 children examined, 17 exhibited considerable hesitation before answering correctly, while 33 confused it with another letter (in 30 instances with p, and in one instance each with b, d, and g). Unfortunately, no comparable data are presented for the letters b, d, p, and g.

While it is evident from the work of both Orton and Hermann that orientation errors may persist well into adolescence, studies by Schonell, Shankweiler, and Naidoo, amongst others, show that such errors do not invariably occur, even in severe cases of reading retardation. Schonell

¹ Hermann used the term "rotations" to describe letter orientation errors and the term "reversals" to describe letter order errors.

(1942) analyzed tests of oral reading (words and prose), spelling (words and prose), and composition given to 103 "backward" readers and 104 normal readers aged from 7 to 13+. About 10% of the children in the whole sample were below average intelligence. The percentage of male backward readers confusing letters in the pairs: b, d; p, q; and m, w, in the course of reading, varied from 85% at 7+ to 15% at 12+ (and 0% at 13+). The percentage of control group boys who confused the same letters in reading varied from 30% at 7+ to 5% at 9+. As far as writing errors were concerned, Schonell found that the percentage of male backward readers who confused letters in the same three pairs varied from 60% at 7+, to 82% at 9+, to 20% at 13+. The comparable figures for control group boys were 15% at 7+, and 8% at 8+. (It is not stated whether a statistical analysis was carried out on these results, but from inspection of the data the differences between groups would appear to be significant.) Although Schonell does not present any information concerning the frequency of orientation errors in the scripts of the backward readers, he does point out that the error rate was higher in this group than in the control group. He also remarks that: "There are only a few cases amongst the backward readers for whom the error is intense and extensive and for whom it represents a definite diagnostic symptom of their faulty perception." (p.162).

Shankweiler's (1964) series of 12 cases, who had been referred to psychiatric clinics on account of educational difficulties, ranged in age from 8:6 to 13:0, were in the average range of intelligence, and all had reading ages below 7:6. Three types of reversal error were defined and placed in the same category for the purposes of analysis: (1) left-right reversal of an individual letter, (2) the type of error

in which the order of letters within a word is transposed (e.g. "warp" for "wrap"), and (3) the reversal of letter order involving the whole word (e.g. "saw" for "was"). Reading reversals and writing reversals were analyzed separately. The nature of the materials on which the analyses were based is not specified, but a child was classified as a reverser if there was at least one occurrence of any of the three types of error. Eight of the twelve children in the series made reversals in reading, and six of these, together with two others, produced reversals in writing. Only two children made no reversals in either reading or writing. Unfortunately, Shankweiler does not give the frequency of occurrence of reversals for those children who produced them.

Naidoo's (1972) sample comprised 98 boys aged between 8 and 13 who were of average, or above, intelligence, and at least two years retarded in either reading or spelling, together with a control group of normal readers. The analysis of orientation errors was based on two short sentences which subjects wrote to dictation. Only 65 of the dyslexic boys were able enough writers to produce legible sentences, and of these 22 made letter reversals. On the other hand, all the control subjects wrote legibly, and only one reversal error was made.

None of the studies described so far enables one to gauge the frequency of orientation errors in the reading and writing of individual retarded readers. Although Monroe's (1932) analysis of reading errors by type and frequency yielded data in the required form, the extent of orientation errors was obscured by the fact that the latter were included in the same category as two other types, viz., transposition of letters and of words. Reading errors made by subjects on three standardized reading tests were classified in terms of ten categories, from which an

error profile was constructed for each of the 415 retarded readers examined. No information about the overall incidence of each class of error was given. Instead Monroe presented a series of error profiles arranged in groups which typify the most commonly occurring patterns. One of these error patterns is characterized by "excessive errors in dealing with the spatial patterns of letters, words, and phrases, as printed or written, so that the child disorients them, transposes the position of letters or their sequence, and repeats words previously read." (p.64). Three cases exhibiting this error profile were described. The first was that of a boy aged 9:5, with an IQ of 106, whose reading age was about 6:6 and in whom the incidence of reversal errors was found to be about 47 per 500 words. The second was a boy aged 10:3 with an IQ of 101 and a reading age of about 7:3 who produced about 43 reversals per 500 words. The third and last case was that of a girl aged 14 with an IQ of 101 whose reading age was about 8:6 and in whom the frequency of reversal errors was about 22 per 500 words. Given the composite nature of Monroe's reversal error category, the frequency of letter orientation errors cannot be precisely estimated; all that can be stated with certainty is that, in the three cases described above, it does not exceed the figures given.

In view of the fact that the majority of authors whose work is described above consider that letter orientation errors are a prominent feature of reading disability, it is surprising that in no case are the results presented in a form clearly indicating their frequency, either in relation to the number of errors of other types, or to the number of opportunities for orientation errors to occur. However, a study by Sidman and Kirk (1974) presents findings which go some way towards making

up for the previous paucity of data. The subjects were 15 children (14 boys and 1 girl), ranging in age from 7:9 to 14:7, who had been referred to a remedial reading clinic and who were considered by the clinic tutors to show a tendency to reverse letters and words. The subjects performed four types of task, namely simultaneous matching-to-sample, delayed matching, oral naming, and writing. There were three versions of each task in which the stimuli, sixteen letters of the alphabet, were presented visually, aurally (except in the case of the naming task), and tactually. The matching and writing tasks were performed with both lower-case (identity task) and upper-case (non-identity task) samples, the comparison stimuli (in the case of the matching tasks) and the written responses (in the writing task) always being lower-case. For the purposes of analysis the set of letters b, d, p, and q was considered separately from the remainder (a, e, f, g, h, j, m, n, r, t, u, y). Non-identity writing and matching tasks and the naming task elicited more orientation errors than the identity tasks, particularly in the case of b, d, p, and q. Considering the results of the non-identity tasks involving the letters b, d, p, and q, the incidence of orientation errors, in terms of errors/opportunity, was about 14% in matching-to-sample, about 10% in naming, and about 5% in writing. The four identity tasks (copying and matching lower-case letters in the visual and tactile modalities) resulted in orientation error frequencies of between 0% and 3% for the letters b, d, p, and q. Between 80 and 90% of all orientation errors were reversals.

In order to evaluate Sidman and Kirk's incidence figures, as a measure of the strength of retarded readers' propensity to make orientation errors, one would need to view them in relation to comparable data from normal readers who are at the same stage of reading. Again, it

is difficult to make this comparison owing to the lack of requisite data. However, the extent of such errors in normal readers may be gauged from a study by Chapman, Lewis and Wedell (1970) in which a sample of 328 school children (177 boys and 151 girls) aged $7\frac{1}{2}$ to $8\frac{1}{2}$ wrote a series of 10 lower-case letters (a, b, d, e, k, m, p, r, s, z) and 7 digits (2, 3, 4, 5, 6, 7, 9) to dictation. Chapman et al. presented the results in a form which showed the percentage of subjects making one, two, and three or more errors, and further analysis of these data showed that, for the boys, the mean frequency of orientation errors, in terms of errors/opportunity, was about 5% for the series of 10 letters. This figure is of the same order as those obtained by Sidman and Kirk, though a direct comparison cannot be made since a task exactly comparable to the dictation test used by Chapman et al. was not included in the former study.

3.2 Letter orientation errors in writing

An analysis of spelling errors, including orientation errors, was carried out for the Schonell Graded Word Spelling Test, Form A. This test was taken by all subjects in the course of the Stage III individual tests, a proportion of boys who performed it at Stage II being re-tested at Stage III. The analysis is concerned with writing errors rather than reading errors because the former were more common and thus provided a more sensitive index. It is hoped to present an analysis of reading errors elsewhere.

Spelling errors were classified in accordance with a scheme put forward by Livingston (1961) and which comprises the following eight categories (with sub-categories shown in parentheses): Confusions (single/multiple), Omissions (single/multiple), Insertions (single/

multiple), Transpositions (adjacent/spaced), Doubling (single (S) for double (D)/double for single), Homophones, Perseverations, and Unclassified. A separate analysis dealt specifically with letter orientation errors (which in the first analysis were classed as Confusions). In the orientation analysis, the letters of the alphabet were divided into two groups, one comprising b, d, p, q, and g (Set 1),¹ and the other the remainder of the alphabet (Set 2). The incidence of orientation errors (i.e. reversals, inversions, and rotations) was measured in two ways. First the number of orientation errors involving letters in Set 1 was expressed as a percentage of the total number of errors occurring on the Schonell Test (i.e. (orientation errors-Set 1)/(total errors) x 100%), and the same was done for the letters in Set 2. Secondly, the number of orientation errors in Set 1 was expressed as a percentage of the total number of occurrences of the letters b, d, p, q, and g in all the words attempted on the Schonell Test (i.e. (orientation errors-Set 1)/(opportunities for error) x 100%). A number of boys in both the retarded reader and control groups had two attempts at a proportion of words in the Schonell Test, the first during the group tests at Stage II and then again in the course of the individual tests at Stage III. If a word was mis-spelt each time, the errors made on both attempts were counted, even if the two mis-spellings were identical.

Table 3.1 shows the results of the spelling error analysis for the retarded readers and the two control groups in each of the three age

¹ The inclusion of the letter g in the same set as b, d, p, and q, has been recommended by Shankweiler and Liberman (1972) because of the low frequency of occurrence of the letter g, and also the fact that, in their study, g was confused with b, d, and p as often as these three letters were confused with themselves. It is true that the letter g does not share exactly the same form as the other four, but the same could be said of the handwritten form of b and q.

Table 3.1 Analysis of spelling errors (Schonell Test): The percentage of errors in each category (in relation to the total number of errors, shown in the last line of the Table) produced by the retarded readers (RR) and normal readers (NR) of the Verbal (VC) and Performance (PC) control groups.

	Group I			Group II			Group III			All Groups		
	RR	NR	NR	RR	NR	NR	RR	NR	NR	RR	NR	NR
	(VC)(PC)			(VC)(PC)			(VC)(PC)			(VC)(PC)		
N	11	11	11	9	9	9	8	10	10	28	30	30
Mean CA	8:5	8:7	8:8	9:1	9:1	9:2	11:1	11:3	11:3	9:5	9:7	9:8
Category of error:												
Confusions												
Single (%)	29	22	22	22	24	25	21	28	22	23	25	23
Multiple (%)	12	25	24	24	20	19	21	22	22	20	22	21
Omissions												
Single (%)	21	21	21	22	22	21	18	16	20	20	19	20
Multiple (%)	11	3	5	2	2	3	8	2	6	6	2	5
Insertions												
Single (%)	9	16	12	10	8	8	16	14	8	11	13	9
Multiple (%)	1	1	2	2	2	1	0	2	0	1	1	1
Transpositions												
Adjacent (%)	4	2	3	4	5	3	4	2	2	4	3	3
Spaced (%)	0	2	2	0	3	4	4	1	1	1	2	2
Doubling												
S for D (%)	9	6	6	5	11	16	4	12	14	5	10	12
D for S (%)	5	1	2	6	3	3	4	2	5	5	2	3
Homophones)												
Persev.) (%)	1	1	2	3	1	1	2	0	0	2	0	1
Unclass.)												
Total number of errors	171	205	188	299	206	200	226	232	248	696	643	636

ranges, and the combined results for the complete sample. The Table presents the analysis based on Livingston's classificatory scheme and shows, for each age range/reading ability subgroup, the frequency of errors in each category as a percentage (rounded to the nearest whole number) of the total number of errors. The divergence between the distributions is greatest in the case of the Doubling category where, with Groups I, II and III combined, the retarded readers made relatively more "double for single" errors and fewer "single for double" errors than both the Verbal ($\chi^2 = 17.01$, $df = 1$, $p < 0.001$ (2-tail)) and Performance ($\chi^2 = 13.68$, $df = 1$, $p < 0.001$ (2-tail)) controls. The latter disparity may be attributed to the fact that opportunities to make "single for double" errors occur only in later stages of the test, which the retarded readers rarely reached. On the other hand, the opportunity to substitute a double letter for a single is more or less constant across the whole range of the test, so that the higher error rate found in the case of the retarded readers probably does reflect a greater degree of uncertainty about this particular spelling rule. In order to carry out a statistical comparison of the overall error distributions the three age ranges were combined, the sub-categories merged, and a single category created for Homophones, Perseverations, and Unclassified, resulting in a total of six categories. A chi-square test of association showed that there were significant differences between the error distribution obtained by the retarded readers and those obtained by the Verbal ($\chi^2 = 11.12$, $df = 5$, $p < 0.05$ (2-tail)) and Performance ($\chi^2 = 14.84$, $df = 5$, $p < 0.05$ (2-tail)) controls. The nature of these differences will not be explored further, as it is not relevant to the issues under consideration.

Table 3.2 Analysis of letter orientation errors (1.o.e.) occurring in the Schonell Test: The numbers of subjects making 1.o.e. (Sets 1 and 2), the total numbers of 1.o.e. (Sets 1 and 2), the percentage of 1.o.e. in relation to the total number of errors (Sets 1 and 2), and the percentage of 1.o.e. in relation to the number of opportunities for error to occur (Set 1).

	Group I			Group II			Group III			All Groups		
	RR	NR	NR	RR	NR	NR	RR	NR	NR	RR	NR	NR
	(VC)	(PC)		(VC)	(PC)		(VC)	(PC)		(VC)	(PC)	
No. of Ss making 1.o.e.												
Set 1	5	1	1	4	1	0	3	0	0	12	2	1
Set 2	2	0	0	0	0	0	0	0	0	2	0	0
No. of 1.o.e.												
Set 1												
Reversals	5/2	2/3	2/3	3/2	0	0	5	0	0	13/4	2/3	2/3
Inversions	0	0	0	0	1	0	1	0	0	1	1	0
Rotations	0	0	0	3	0	0	1	0	0	4	0	0
Total	5/2	2/3	2/3	6/2	1	0	7	0	0	18/4	3/3	2/3
Set 2												
Reversals	1/1	0	0	0	0	0	0	0	0	1/1	0	0
Inversions	1/2	0	0	0	0	0	0	0	0	1/2	0	0
Rotations	0	0	0	0	0	0	0	0	0	0	0	0
Total	2/3	0	0	0	0	0	0	0	0	2/3	0	0
No. of 1.o.e. (all types)/total no. errors (%)												
Set 1	2.9	1.0	1.1	2.0	0.5	0.0	3.1	0.0	0.0	2.6	0.5	0.3
Set 2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
No. of 1.o.e. (all types)/no. of opportunities for error (%)												
Set 1	3.4	0.9	0.9	3.3	0.4	0.0	4.6	0.0	0.0	3.3	0.4	0.2

Note: Where an entry showing the number of 1.o.e. consists of two numbers separated by a virgule, the second refers to the number of self-corrected errors made in addition to those which went uncorrected, shown by the first.

Table 3.2 is devoted to the analysis of orientation errors, in terms of the measures already described. Where an entry consists of two numbers separated by a virgule, the second refers to the number of self-corrected errors made in addition to those which went uncorrected (shown by the first number). Not counting cases where all errors were self-corrected, thirteen of the retarded readers (six in Group I, four in Group II, and three in Group III) made at least one orientation error involving letters in Set 1 and/or Set 2, compared with two of the normal readers (one boy in Group I and one in Group II). No subject made more than three orientation errors in the course of the Schonell Test and for the complete group of retarded readers the mean percentage of errors per opportunity (3.3%) is somewhat below the figure (5%) obtained by Sidman and Kirk for their writing task. On the face of it an error rate of this magnitude would be more likely to result from momentary lapses of attention, rather than a sustained perceptual or cognitive deficiency. Nevertheless, as will be shown in the final section of this chapter, it is possible to demonstrate that the retarded readers who made orientation errors differ, in certain aspects of cognitive performance, from both the normal readers and the retarded readers who were free of these errors.

3.3 The acquisition of spatial concepts

3.3.1 The horizontal and vertical axes

Introduction

In Chapter 1 the work of Piaget and Inhelder (1956) on the development of physical reference systems was examined, to determine whether it

could contribute to an understanding of how children learn to judge egocentric orientation, but no firm conclusions were reached. However, in view of the work of Inhelder (1962) and Lovell et al. (1964), who found an association between reading difficulty and delayed development of spatial concepts, it seemed worthwhile to explore this aspect of cognitive development in greater depth. The purpose of the experiment reported in this section is to establish the level reached by subjects in the conceptualization of the horizontal and vertical, in order to relate it to (1) level of attainment in reading and spelling, and (2) propensity to make orientation errors.

Procedure

Piaget and Inhelder used a variety of different techniques to investigate euclidean concepts, two of which were selected for this experiment.

The child's conception of the horizontal was evaluated in the following way. He was shown a flask about one-quarter full of coloured liquid and asked to imagine how the surface would appear when the flask was tilted at various angles. Seven full-scale drawings were presented in turn, each of which showed an outline of the empty flask, at a different inclination, resting on a horizontal line (representing the surface of the table). (In Piaget and Inhelder's study the outline drawing did not show the table; instead it was drawn in by the child before his attempt at the surface of the liquid.) The drawings showed the flask with its principal axis inclined at 0° , 30° , 60° , 90° , 120° , 150° , and 180° to the vertical, the series being presented in fixed

random order. The child was asked to draw a straight line representing the surface of the water, and as each outline was presented he was reminded that the horizontal base line represented the table. After he had completed the seven drawings with the flask upright throughout, he was shown each one again in the same order, but this time the flask was tilted to the same angle as shown in the drawing. The child was invited to compare the line he had drawn with the situation now before him, and to draw a new line if he thought his first attempt was incorrect. This procedure was carried out first with a straight-sided flask (approx. dimensions: 8" high x 4" wide) and then with a round-bottomed flask (approx. dimensions: 7" high x 5½" wide).

The method used to evaluate the child's conception of the vertical employed a flask in which a model fish was suspended by a line from a rod running through its neck. The procedure was basically the same as for the evaluation of the horizontal, except that only the straight-sided flask was used. This technique was supplemented by one in which the child was asked to draw a series of trees "nice and straight" on an outline drawing of a mountain (gradient of slope 1:1).

Results

The majority of lines which subjects drew to represent the water level and the plumb-line showed some degree of curvature. In these cases the direction of the line was defined by a straight line passing through the two points at which the child's line intersected either the sides of the flask, or the tip of the rod and the fish, as the case may be.¹

¹ A least-squares approximation to the line would probably have afforded a truer estimation of its slope, but application of this technique to the 1260 protocols would have been extremely time-consuming.

For the purpose of scoring the water-level and plumb-line tests, a child's drawing was considered to be correct provided that the orientation of his line was within 8° of the true horizontal or vertical. This criterion is stricter than some that have been used in recent studies (Kackay, Brazendale and Wilson, 1972; Sheppard, 1975), but it was chosen because it reflected the accuracy achieved by boys in this sample when the flask was in the three positions most conducive to success, viz., inclinations of 0° , 90° and 180° . Of the 540 lines drawn in the course of the two water-level tasks and the plumb-line task in respect of these three positions, 95% were within 8° of the true direction.

In the case of the water-level, plumb-line and trees-on-mountain tasks, correct drawings were awarded a score of 1 and incorrect drawings a score of 0. For each of the two water-level tasks (straight-sided flask; round-bottomed flask) and the plumb-line task (straight-sided flask) the total score ranged from 0 to 7. In terms of the developmental stages proposed by Piaget and Inhelder, a score of 1 corresponds to Stage IIA, a score of 2 to Stage IIB, a score of 3 to a transitional stage between IIB and IIIA, a score of 4, 5, or 6 to Stage IIIA, and a score of 7 to Stage IIIB (Sheppard, 1975). As was noted above, the drawings showing the flask inclined at 0° , 90° , and 180° presented little difficulty to boys in this sample, whether retarded or normal readers, so that the great majority of scores fell in the range 3 to 7.

In the trees-on-mountain task it was found that 95% of trees drawn on the base and summit had their axes aligned within 9° of the vertical, and, following the procedure used in the other tasks, the orientation was judged to be correct provided that it fell within this range.

Children were usually requested to draw one tree on the summit, two on the base, and three on the slope, although the outcome did not always conform to this instruction. In these circumstances the developmental sequence may be defined in the following way. Trees drawn vertically on the base and summit, but perpendicular to the slope are characteristic of Stage IIA. At Stage IIB some or all of the trees on the slope are shown at an angle between the perpendicular and the vertical (the remainder, if any, being perpendicular). One vertical tree on the slope marks a transitional stage between IIB and IIIA, while Stage IIIA is reached when the slope is shown with at least two vertical trees, but still with one or more drawn incorrectly. Finally, at Stage IIIB, all trees on the slope (and elsewhere) are drawn vertically. Children who produced off-vertical trees on the base or summit, or both, were eliminated from the classification (six subjects), unless all their slope trees were vertical, in which case they were placed at Stage IIIA.

Table 3.3 presents separate analyses of the water level, plumb-line, and trees-on-mountain tasks, showing the number of subjects at each developmental stage for all three age ranges, and also for the combined sample. In the case of the first three tasks, there are two distributions within each age range/reading ability subgroup, one (Pre-Demonstration, or Pre-D) based on the first series of lines drawn with the flask upright, and the other (Post-Demonstration, or Post-D) derived from the series drawn with the flask tilted. (If the subject was satisfied with the angle of his first line, the same orientation was recorded for both Pre-D and Post-D drawings.) For the sample as a whole, the numbers of retarded and normal readers at each stage in the developmental sequence were compared by means of a 2×3 chi-square test of association, or if the expected frequencies in some cells were too low by reducing the array

Table 3.3 The acquisition of the concepts of the horizontal and vertical by the retarded and normal (Performance control) readers of Groups I, II, and III.

	Group I		Group II		Group III		All Groups		Chi-Sq. (2x3) Value	FEP Sig. Level (2-tail) (2-tail)
	RR	NR	RR	NR	RR	NR	RR	NR		
Mean CA	9:3	9:4	9:8	9:7	11:6	11:9	10:2	10:2		
Horizontal/Straight-sided/Pre-D										
Stage										
IIA	0	0	0	0	0	0	0	0		
IIB	0	1	0	0	0	0	0	1		
IIB-IIIA	4	4	2	2	1	4	7	10	2.20	NS
IIIA	7	6	6	6	5	5	18	17		
IIIB	0	0	1	1	4	1	5	2		
Horizontal/Straight-sided/Post-D										
Stage										
IIA	0	0	0	0	0	0	0	0		
IIB	0	0	0	0	0	0	0	0		
IIB-IIIA	0	0	2	0	0	1	2	1		
IIIA	8	10	6	8	5	5	19	23	p=0.55	
IIIB	3	1	1	1	5	4	9	6		
Horizontal/Round-bottom/Pre-D										
Stage										
IIB	0	0	1	0	0	0	1	0		
IIB-IIIA	3	3	1	5	2	4	6	12		
IIIA	5	4	4	1	3	1	12	6	3.36	NS
IIIB	3	4	3	3	5	5	11	12		
Horizontal/Round-bottom/Post-D										
Stage										
IIB-IIIA	0	0	1	0	0	0	1	0		
IIIA	2	5	3	5	1	2	6	12		
IIIB	9	6	5	4	9	8	23	18	p=0.27	
Vertical/Straight-sided/Pre-D										
Stage										
IIA	0	1	1	0	0	1	1	2		
IIB	0	1	0	0	1	1	1	2		
IIB-IIIA	3	0	2	3	0	3	5	6		
IIIA	8	9	6	5	4	2	18	16	0.76	NS
IIIB	0	0	0	1	5	3	5	4		
Vertical/Straight-sided/Post-D										
Stage										
IIA	0	1	0	0	0	0	0	1		
IIB	0	0	1	0	0	1	1	1		
IIB-IIIA	0	1	0	4	0	2	0	7		
IIIA	9	8	8	4	6	4	23	16	7.75	p<0.05
IIIB	2	1	0	1	4	3	6	5		
Vertical/Trees-on-mountain										
Stage										
IIA	0	1	2	0	0	0	2	1		
IIB	0	1	0	3	1	1	1	5		
IIB-IIIA	1	0	2	1	1	1	4	2	2.36	NS
IIIA	2	1	2	0	0	1	4	2		
IIIB	7	6	3	5	6	6	16	17		

to 2 x 2 and applying the Fisher exact probability (FEP) test. The manner in which adjacent cells were combined is indicated in the Table by dotted lines showing the boundaries within which cells were amalgamated. According to Cochran (1954) the chi-square test should be used only if fewer than 20% of the cells have an expected frequency of less than 5 and if no cell has an expected frequency of less than 1. While the second condition was always met, there were two instances (Hor./Str.-sided/Pre-D and Vert./Str.-sided/Pre-D) where the second condition just failed to be met (33% of the cells had expected frequencies less than 5). However, all the 3 x 2 tables met the somewhat less stringent conditions suggested by Ferguson (1959), viz., no expected frequency less than 2. Where the expected frequencies violated Ferguson's condition the array was reduced to 2 x 2 and the Fisher exact probability test applied.

In contrast to the finding of Inhelder and of Lovell et al. the normal readers were no more advanced than the retarded readers in the acquisition of the horizontal and vertical concepts. Indeed, on one of the tasks (Vertical/Straight-sided/Post-D) there were significantly¹ more normal readers at the earlier stages of the sequence, a difference which had not been apparent at the pre-demonstration stage of the same task, and which seems to suggest that, at least in this task, direct perception of the vertical assists the retarded readers more than it does the normal readers.

¹ In the case of the statistical tests reported in Table 3.3 the level of significance at which the null hypothesis is rejected is 0.05 and refers to a 2-tailed region of rejection, since the differences are in the opposite direction to the one predicted. Elsewhere in this chapter, if the region of rejection is not specified it may be assumed to be 1-tailed.

In a further analysis based on the raw scores (i.e., the numbers of correctly-oriented lines) a series of Wilcoxon matched-pairs signed-ranks tests was carried out, comparing the performance of the retarded readers with that of the normal readers (Performance control group) in each age range and on each task (except trees-on-mountain), with separate analyses of the Pre-D and Post-D situations. It was found that in each age range the retarded readers were more advanced than the normal readers on all three tasks (both Pre-D and Post-D), though the differences in performance did not reach significance even when the comparisons involved the whole sample.

3.3.2 Binary relations in projective space: left-right, above-below, and further-nearer.

Introduction

In general, projective relations are those between an object and the observer, or between two or more objects in relation to the observer. Viewed in Piagetian terms, the development of binary concepts involves a process of progressive decentration which takes place in three stages. In the first (egocentrism) the relations have an absolute character in that they are defined solely from the child's own point of view. At the second (socialization) the child recognizes the relativity of the terms and is able to put himself in the place of a person whose perspective is different from his own. The third (objectification) is marked by the recognition of a further degree of relativity, when the child is able to consider relations which involve putting himself in the place of the objects themselves. The age of accession to each stage is not the same for the three relations. Thus at the egocentric stage, left and right

are not correctly identified until some time after the child has become familiar with top-bottom and front-back, a delay which reflects the bilaterally-symmetric structure of the body. There is a further horizontal decalage at the stage of socialization when left-right and before-behind relations are usually a greater source of confusion than above-below, because in everyday situations the longitudinal axes of our bodies are similarly oriented so that we share the same perspective on the above-below dimension, whereas the relationship between our left-right and front-back axes is constantly varying. Furthermore, the work of Piaget and Inhelder on the coordination of perspectives (three-mountains task) showed that, at the socialization stage, before-behind relations are somewhat easier for the child to handle than left-right relations. The explanation offered for this tendency was that action taking place in the before-behind dimension is relatively more effective in promoting familiarity with this relation than is lateral motion in facilitating left-right awareness. However, the chronological intervals involved in these decalages are a matter of speculation at present since the above-below and before-behind relations have not been the subject of such systematic investigation as the left-right relation.

Procedure

(i) Left-right relations

The stage reached by the child in the progressive acquisition of the left-right concept was determined by means of a series of four tests. In Test 1, the child was seated facing the examiner and asked to identify in turn his right hand, left ear, right leg, and left hand. The series of questions, which were asked in the above order, was designed so that

the same body part was not designated twice in a row (i.e. right then left, or vice versa). Children who are not sure which is the right and the left nevertheless know that they are opposites and often adopt an "alternating" strategy. The refocussing of attention which occurs when a different body part is mentioned tends to disrupt this strategy and helps reduce the possibility of it producing a complete series of correct (or incorrect) responses by chance, an important consideration in view of the fact that in scoring the test, systematic errors and systematic successes are, for certain purposes, given equal weight.

Test 2 was concerned with a further aspect of the egocentric phase of development, namely, whether correct use of the terms left and right could be extended to two objects situated on opposite sides of the mid-line. It is possible for the child to make this kind of judgment before he reaches the stage of objectification, since a problem of the form: "Is X to the left or right of Y?" can be answered correctly if it is reduced to the absolute form: "Is X to the left or right?" The test was performed with pairs of coloured blocks which were placed either side-by-side, or in line on the table directly in front of the subject. The experimenter, who sat at the side of the table (at right angles to the subject's line of regard) asked a series of questions of the form: "Is one block to the left (right) of the other?" If the subject answered "Yes", he was asked: "Which block?" There were twelve arrangements altogether, eight of which were pairs of side-by-side blocks (nos. 2, 3, 5, 6, 7, 8, 11, 12), the remainder being in-line blocks. Questions concerning arrangements 2, 4, 5, 6, 9 and 12 contained the term "left", and the remainder contained the term "right".

Test 3 was designed to reveal whether the child had reached the

stage of socialization. The procedure was similar to that of Test 1, except that the subject was asked to identify parts of the examiner's body. The same body parts were designated in the same order.

In the last test (4) the child identified the relative position of three coloured blocks arranged in a row from left to right. There were two series of arrangements: 4a and 4b. The first called for judgments to be made with the blocks in view; in the second, the blocks were presented for 10 seconds and then hidden from view before the questions were put. There were eight arrangements in each series, and two questions per arrangement, each of the form: "Is the X block to the left or right of the Y block?" On the first four arrangements of each series the child was asked to identify the position of one end block in relation to either the other end or the middle block. On the remaining four arrangements of each series the child was asked to identify the position of the middle block in relation to one of the end blocks. The block arrangements and the accompanying questions were identical for Tests 4a and 4b, but were not presented at the same session.

(ii) Above-below relations

It was assumed in the light of previous studies (De Villiers and De Villiers, 1974; Harris and Stromman, 1972) that boys in the present sample would have no difficulty in identifying the intrinsic top, bottom, front, and back of either persons or objects, and for this reason no tests equivalent to 1 and 3 above were given. (It is not certain to what extent the reported tendency of some retarded readers to confuse a term with its opposite applies to the relations above-below and before-behind, but any tendency to make such errors would be revealed by

performance on Test 2.) Though it was considered unlikely that the majority of subjects, whether retarded or normal, would not have also achieved complete objectification of above-below relations, it was thought that demonstration of this fact would be of significance if, at the same time, it were shown that retarded readers were not as advanced in their conception of the left-right relation, since the results of the above-below tests would provide a partial control for attentional factors (on the assumption that the latter would be unlikely to differentially affect performance levels on tasks involving the three relations). Accordingly, the child's understanding of the above-below relation was assessed using tests which were homologous with Tests 2 (two-block arrangement) and 4 (three-block arrangement) of Section 3.3.1.

(iii) Further-nearer relations

The use of the terms further and nearer, rather than in front of and behind, was thought to be slightly more natural in this situation where the objects concerned did not possess intrinsic fronts and backs. The child's understanding of these concepts was examined in the same way as his conception of above and below, that is to say by means of tests homologous with Tests 2 and 4 of section (i) (Left-right relations), using series of blocks arranged in a horizontal row on the mid-line.

Scoring Criteria

(i) Left-right relations

On the basis of a detailed analysis of performance on tests of left-right relations, Laurendeau and Pinard (1970) proposed a set of scoring criteria which define the stage reached on the developmental scale, and the same procedures, with minor modifications noted below,

were used in the present study. The types of behaviour characteristic of each stage are described here in full, but for a complete account of the rationale of the scoring scheme the reader is referred to the above study. Test 2 (two-block arrangement) was not used by Laurendeau and Pinard in defining the developmental scale and consequently will not be discussed in this section.

The principal feature of the scoring method is that, in general, a child is considered to have reached a particular stage only if he achieves 100% success on the test or tests which define that stage.

Children who show no comprehension of left and right and whose performance is at chance level (50% correct responses) or characterized by only partial success on all three tests (1, 3 and 4) are classified as being at Stage 0.

The essential characteristic of Stage I is recognition by the child that left and right refer to sides of the body which are opposed in a consistent and stable manner. On this definition consistent errors of labelling, in which right is substituted for left, and vice versa, are not penalized, but receive the same score as a series of systematic successes. In determining membership of Stage I, which is sub-divided into Stage IA - a transitional stage - and Stage IB, performance on both Test 1 (left-right relations on the subject's own body) and Test 3 (left-right relations on another person's body) is taken into account. Children at Stage IA have a weakly established concept of left-right in that they achieve systematic successes or errors on Test 1 but then revert to random responding or a strategy irrelevant to the concept on Test 3, or vice versa. Thus any of the four types of behaviour summarized in Table 3.4 can serve to place a child at Stage IA.

Table 3.4 Behaviour types defining Stage IA of the developmental scale.

Type	Test	
	1	3
A	Systematic successes (4/4)	Chance responses (2/4)
B	Systematic errors (0/4)	Chance responses (2/4)
C	Chance responses (2/4)	Systematic successes (4/4)
D	Chance responses (2/4)	Systematic errors (0/4)

In Substage IB the concepts of left and right become more stable in that successes are achieved on both problems, and in some cases (behaviour types C, D, E, and F¹) the first attempts at decentration become apparent. The complete set of behaviour types characteristic of Substage IB is shown in Table 3.5.

¹ The cognate behaviour types E and F (not used by Laurendeau and Pinard) occurred infrequently and their inclusion in Substage IB was thought preferable to excluding them altogether.

Table 3.5 Behaviour types defining Stage IB of the developmental scale.

Type	Test	
	1	3
A	Systematic successes (4/4)	Systematic errors (0/4)
B	Systematic errors (0/4)	Systematic successes (4/4)
C	Systematic successes (4/4)	Partial successes (1/4, 3/4)
D	Systematic errors (0/4)	Partial successes (1/4, 3/4)
E	Partial successes (1/4, 3/4)	Systematic successes (4/4)
F	Partial successes (1/4, 3/4)	Systematic errors (0/4)

It was not altogether satisfactory to classify a score of 1/4 as a partial success, in the same category as a score of 3/4, but the reason for doing so is that it is consistent with the line of reasoning already advanced in which scores of 4/4 and 0/4 are given equal weight. It is easier to see the merit of this procedure when more than four questions are included in each test. In fact, Laurendeau and Pinard used six, and defined partial success as either a single error or success, or two errors or successes. They also consider that four questions are insufficient to distinguish a series of chance successes from responses that are based on a genuine knowledge of left and right. (Assuming that the child responds on a chance basis and that successive responses are independent of each other, then the probability of correct responses being given to a series of four questions is 0.063, four times greater than in the case of a six-question series.) In designing the test, it was thought that four questions per test would be sufficient since accession to Substage IB is based on the results of Tests 1 and 3 (i.e., eight questions). However, when it came to scoring the test it was realised that, while eight questions almost certainly provide an adequate safeguard against chance successes in the case of behaviour types A and B, four questions cannot provide the same safeguard against partial successes in the case of behaviour types C, D, E, and F. As it was too late to remedy this shortcoming the test was scored in a manner which was analogous to the procedure used by Laurendeau and Pinard, though in the circumstances it might have been more realistic to class a score of 1/4 as a chance response, particularly as there were few subjects in the present sample who consistently reversed left and right.

At Stage II the egocentric mode of responding to questions about the examiner's body is abandoned as the child learns to appreciate that left-right relations depend on the point of view of the person making the judgment. Systematic reversals are still counted as successes provided that the child's responses take account of the different viewpoints. The types of behaviour which place a child at this stage are shown in Table 3.6.

Table 3.6. Behaviour types defining Stage II of the developmental scale.

Type	Test	
	1	3
A	Systematic successes (4/4)	Systematic successes (4/4)
B	Systematic errors (0/4)	Systematic errors (0/4)

In general, children at Stages IA, IB, and II have limited success with Tests 4a and 4b, insofar as they often respond correctly to questions which refer to end blocks, but their lack of objectification of the concept results in recourse to chance responses or an incorrect (albeit consistent) strategy on questions relating to middle blocks.

It was assumed by Laurendeau and Finard that the child had attained a completely objectified concept of left-right if he achieved 100% success on both Test 4a and 4b. Moreover, they found that Test 4b (three hidden blocks) is not appreciably more difficult than Test 4a (three visible blocks), and therefore the main consequence of demanding perfect performance on both rather than one or the other was to provide greater assurance that success is not attributable to chance responses. However, in Laurendeau and Finard's study Tests 4a and 4b contained six questions each, only two of which referred to middle blocks. Now it is the latter type of question which serves to determine whether the child's concept of left-right has assumed the highest form of relativity; questions about end blocks can be answered correctly by a child who has not advanced beyond Stage II. In view of the fact that, in this study, accession to Stages I and II was dependent on the child's responses to eight questions (four in Test 1 and four in Test 3) it was thought appropriate to use the same number to determine whether the final Stage had been reached (taking into consideration only those questions which refer to middle blocks). It will be recalled that Test 4a and 4b both consisted of eight arrangements of blocks, with two questions per arrangement, and that questions on the first four arrangements referred to end blocks and on the last four to middle blocks. Therefore, in order to base the scoring procedure on the requisite number of questions about middle blocks, the child's total score was composed of his responses to arrangements 1 and 2 (involving four questions about end blocks) and 5 and 6 (involving four questions about middle blocks) in each of the two series comprising Test 4a and 4b. In order to be placed at Stage III it was necessary for the child to answer all sixteen questions correctly.

(ii) Above-below relations

Certain stages of the developmental scale (IA, IB, and II) could not be studied as the appropriate tests were not performed. However, successful performance on Test 2 was assumed to characterize an advanced phase (IC) of Stage I. The creation of a distinct substage for this level of development seemed to be justified in view of the work of Piaget (1924) and Elkind (1961) which showed that the child is unable to judge the relative position (left or right) of two external objects before the age of 7 or 8, or about two years after he is able to identify the sides of his body. It is not known whether the same period of time separates the corresponding levels in the development of the above-below concept, but it would be safe to assume that the child does not reach the later phase before he has learnt to identify the intrinsic top and bottom of persons or objects. Accordingly, the child is deemed to have reached Substage IC when he succeeds in answering all eight questions of Test 2 correctly. A series of systematic errors would also qualify the subject for inclusion in Substage IC, though no cases of such behaviour occurred in this study.

Complete objectification of the above-below relation (Stage III) was examined by means of tests homologous with those employed in the assessment of left-right relations (4a and 4b), and accession to this stage was therefore governed by the same criterion, that is, 100% success on arrangements 1, 2, 5, and 6 of Test 4a and 4b.

It was assumed that children who failed both Test 2 and Test 4 were at a stage between 0 and IB, while children who failed 2 but succeeded on 4 were excluded from the classification.

(iii) Further-nearer relations.

The tests employed to assess the development of the concepts of further and nearer were homologous with the above-below tests. They therefore served to define comparable levels on the developmental scale, viz., Stage IC and Stage III, and were scored according to the same criteria.

Results

It may be seen from Table 3.7 that when the results from Groups I, II, and III were combined there were no significant differences between the retarded readers and either of the control groups with regard to their level of understanding of any of the three projective relations. However, the small differences which did exist resulted from the more advanced performance of the normal readers, and these were most marked in the case of the left-right concept, where there was a tendency for there to be more normal readers at Stage III, compared with the number of retarded readers, and correspondingly fewer at Stage II. Only two retarded readers - both members of Group I - completely failed to oppose left and right on their own body in a consistent manner. There were also three subjects who systematically reversed left and right on at least some of the tests: a Group I normal reader (performance unclassifiable) who made systematic reversals on Test 3 but went on to successfully complete Tests 4a and 4b; a Group II retarded reader at Stage IB who achieved partial success on Test 1 but made

Table 3.7 The comprehension of binary relations in projective space:
Distribution on the developmental scale of the retarded
and normal readers of Groups I, II, and III.

	Group I			Group II			Group III			All Groups		
	RR	NR (VC)	NR (FC)	RR	NR (VC)	NR (FC)	RR	NR (VC)	NR (FC)	RR	NR (VC)	NR (FC)
Left-right												
Mean CA	9:5	9:5	9:6	9:10	9:8	9:9	11:6	11:8	11:10	10:3	10:3	10:4
Stage												
O	2	0	0	0	0	0	0	0	0	2	0	0
IA	1	0	0	1	1	0	0	0	0	2	1	0
IB	0	4	4	1	0	0	1	0	0	2	4	4
II	6	5	4	3	4	4	8	3	5	<u>17</u>	<u>12</u>	<u>13</u>
III	2	1	2	2	4	5	1	7	4	<u>5</u>	<u>12</u>	<u>11</u>
Uncl.	0	1	1	2	0	0	0	0	1	2	1	2
Difference between RR and NR(VC) (All Groups) NS ($\chi^2 = 3.82$, df = 2)												
Difference between RR and NR(FC) (All Groups) NS ($\chi^2 = 3.18$, df = 2)												
Above-below												
Mean CA	9:3	9:4	9:4	9:9	9:7	9:9	11:8	11:9	11:10	10:2	10:3	10:3
Stage												
O-IB	2	1	1	0	0	0	0	1	0	2	2	1
IC	7	7	7	5	4	3	4	2	3	16	13	13
III	2	3	3	4	5	6	5	7	7	<u>11</u>	<u>15</u>	<u>16</u>
Uncl.	0	0	0	0	0	0	1	0	0	1	0	0
Difference between RR and NR(VC) (All Groups) NS (p = 0.25, FEP Test)												
Difference between RR and NR(FC) (All Groups) NS (p = 0.18, FEP Test)												
Further-nearer												
Mean CA	9:4	9:4	9:5	9:9	9:8	9:9	11:8	11:9	11:11	10:3	10:3	10:4
Stage												
O-IB	2	1	1	1	2	1	1	3	2	4	6	4
IC	8	9	9	7	3	4	4	2	6	<u>19</u>	<u>14</u>	<u>19</u>
III	1	1	1	1	3	3	2	5	2	<u>4</u>	<u>9</u>	<u>6</u>
Uncl.	0	0	0	0	1	1	3	0	0	3	1	1
Difference between RR and NR(VC) (All Groups) NS ($\chi^2 = 3.01$, df = 2)												
Difference between RR and NR(FC) (All Groups) NS ($\chi^2 = 0.33$, df = 2)												

systematic errors on Test 2, 3, and 4a; and a Group III retarded reader at Stage II who made systematic errors on Test 4b. Although the performance of the retarded readers was, on the whole, similar to that of the normal readers, the data of Table 3.7 conceal significant differences between the retarded readers who made letter orientation errors and those who did not. This finding will be examined in greater detail in the next section.

It is of interest to note that, in terms of the numbers at Stage III, subjects appear to be no more advanced in their conception of further-nearer than they are in their understanding of left-right relations. An analysis of performance on Test 4 by means of the Wilcoxon matched-pairs signed-ranks test showed that while a subject's score on the further-nearer test was usually higher than that on the left-right test, the difference did not reach the $p = 0.05$ level of significance for either the retarded readers ($N = 24$, $T = 127$), the Verbal control group ($N = 16$, $T = 39$), or the Performance control group ($N = 17$, $T = 67$).

The finding that retarded readers are somewhat more advanced than normal readers in the conceptualization of euclidean space, while at the same time being slightly delayed in the acquisition of projective concepts suggests that the inter-relationship between these two aspects of development may be different in the two groups. If, as Piaget maintains, concepts of euclidean and projective space develop together and are mutually interdependent, one would anticipate finding a close association between developmental stages in normal readers, but a weaker association in retarded readers on account of the delayed

development of projective concepts. This issue was explored by computing Spearman rank order correlation coefficients between subjects' rankings on the three projective scales and their rankings on three of the axes of reference tests (Table 3.8). (On each scale subjects' rankings ranged from 1 to 3, corresponding to Stages O-IB, II (or IC), and III, respectively, of the projective scale, and Stages IIA/B-IIIA, IIIA, and IIIB of the horizontal/vertical scales.) Contrary to what might be predicted on theoretical grounds, retarded readers evinced a closer correspondence between the levels reached in the conceptualization of projective and euclidean space than did the normal readers. These inter-relationships reached significant levels for the retarded readers when the stage of their euclidean development was correlated with their position on the scale of left-right concepts. The implications of these findings will be considered in more detail at a later stage.

3.4 The relationship between the incidence of letter orientation errors and some aspects of cognitive development, including the conceptualization of space.

The two experiments described in this chapter failed to demonstrate any significant differences between retarded and normal readers in the acquisition of euclidean and projective concepts. However, if poorly developed spatial concepts are to be found only in those children who exhibit confusion about letter orientation, then it is conceivable that the overall results obscure developmental differences between sub-groups of retarded readers. With a view to examining this question the retarded readers in Groups I, II, and III were divided into two sub-groups, one consisting of all subjects who made one or more orientation errors in the course of the Schonell Spelling Test ($N = 13$) and the other consisting of

Table 3.8 Measures of association (in terms of Spearman rho) between subjects' rankings on projective and euclidean scales.

	<u>Measure of Projective Development</u>					
	<u>Left-right</u>		<u>Above-below</u>		<u>Further-nearer</u>	
	RR	NR(PC)	RR	NR(PC)	RR	NR(PC)
<u>Measure of Euclidean Development:</u>						
Hor./Rnd./Pre-D	0.47**	-0.21	0.22	0.18	0.18	0.07
Hor./Str./Pre-D	0.64**	0.07	0.24	-0.04	0.20	0.07
Vert./Str./Pre-D	0.37*	0.07	0.20	0.07	-0.02	-0.16

* Value of coefficient significantly different from zero, $p < 0.05$ (1-tail test)

** Value of coefficient significantly different from zero, $p < 0.01$ (1-tail test).

boys who made no such errors ($N = 15$). Two retarded readers (both in Group III) could not be included in either subgroup, in one case because the test was inadvertently omitted, and in the other because the boy's difficulty was so severe that not one word was attempted. Before describing the performance of these subgroups on the tests of euclidean and projective concepts it is instructive to compare their intellectual abilities and levels of scholastic attainment. As originally constituted the two subgroups did not have the same number of members, there being a greater proportion of Group II and Group III boys amongst those who made no orientation errors than amongst the other subgroup. This imbalance could have introduced spurious differences between the two subgroups on certain measures, and the numbers in each age range were therefore equalized by excluding from the analysis one Group II and two Group III boys who made no orientation errors and one Group I boy who made at least one, with the result that each subgroup was ultimately composed of 12 members. (The individuals who were excluded were those at the end of the lists when members of Groups I, II, and III were listed alphabetically by the initial letter of their surname.) Table 3.9 shows that the two subgroups were very well matched with regard to chronological age and Performance IQ. There were also no significant differences in respect of Verbal IQ, Mental Age, Achievement Quotient, and Reading Age (Comprehension), although there was a tendency for the boys who made no orientation errors to achieve higher mean scores on these measures. However, the occurrence of letter orientation errors was clearly associated with the level of attainment in reading and spelling, such errors being produced chiefly by retarded readers who had made the least progress.

Table 3.9 Intellectual ability and reading and spelling attainment in retarded readers: A comparison of subjects who produced orientation errors on the Schonell Test (Subgroup A) and those who did not (Subgroup B)

	Retarded Readers				t test (1-tail)	
	Subgroup A		Subgroup B		Value	Sig. Level
	Mean	SD	Mean	SD		
CA ¹	9:3	1:1	9:3	1:2	0.01	NS
VIQ	106	10	112	13	-1.27	NS
PIQ	113	11	114	7	-0.21	NS
MA	10:2	1:4	10:6	0:11	-0.43	NS
RA (Acc)	7:5	0:7	7:11	0:7	-2.13	p<0.05
RA (Comp)	7:11	1:0	8:5	1:1	-1.21	NS
AQ	72.9	5.5	75.4	4.1	-1.28	NS
SA	6:8	0:9	7:2	0:5	-1.79	p<0.05

¹ CA at time of Schonell Test.

Table 3.10 WISC subtest performance of retarded readers: A comparison of subjects who produced orientation errors on the Schonell Test (Subgroup A) and those who did not (Subgroup B).

	Retarded Readers				t test (1-tail)	
	Subgroup A		Subgroup B		Value	Sig. Level
	Mean	SD	Mean	SD		
<u>Verbal Scale</u>						
Similarities	14.3	1.5	15.4	2.4	-1.45	NS
Vocabulary	11.0	2.1	13.3	2.2	-2.65	p<0.05
Arithmetic	10.1	2.6	10.4	3.1	-0.28	NS
Digit Span	8.3	2.3	8.0	2.3	0.27	NS
<u>Performance Scale</u>						
Block Design	12.7	3.9	13.8	3.4	-0.79	NS
Object Assembly	13.4	3.1	13.1	1.8	0.32	NS
Picture Completion	10.4	2.7	11.7	1.7	-1.36	NS
Picture Arrangement	12.5	2.9	11.3	1.4	1.25	NS
Coding	10.4	2.4	10.1	3.0	0.30	NS

In view of the fact that the Verbal IQ difference approached significance the WISC results were examined in more detail to determine how performance on the various subtests of the Verbal Scale had contributed to this difference. The same was done in the case of the Performance Scale, for although the two subgroups' mean scores were almost identical it seemed advisable to verify that the IQ score did not mask subtest differences which balanced each other out. Table 3.10 shows that there were no significant differences between the two subgroups, except in the case of the Vocabulary subtest where the performance of the retarded readers who exhibited orientation confusion was markedly inferior to that of the other subjects. In the normal course of development the nine-year-old child would take about 15 months to progress from the less advanced to the more advanced vocabulary level, and it is therefore unlikely that the difference between the two subgroups can be attributed solely to the disparity in their reading ages.

For the next stage of the analysis Subgroups A and B were restored to their original size, namely 13 and 15 subjects respectively, as the mean CA of neither was significantly different from that of the Performance control group. An examination of the association between the tendency to confuse orientation and the stage reached in the development of euclidean concepts (Table 3.11) showed that, while the retarded readers who produced orientation errors were not as advanced as those who did not do so, neither Subgroup's performance was significantly different from that of the control group except in the case of two of the tests (Horizontal/Round-bottomed flask/Post-D and Vertical/Straight-sided/Pre-D) where the subjects of Subgroup B excelled. When the subjects of Subgroup A were compared directly with those of Subgroup B

Table 3.11 The acquisition of the concepts of the horizontal and vertical: Distribution on the developmental scale of the normal readers (Performance control) and retarded reader Subgroups A (orientation errors present) and B (orientation errors absent).

Mean CA	Normal Readers (PC) (Groups I, II, III)		Retarded Readers Subgroup A Subgroup B	
Stage				
Horizontal/Straight-sided/Pre-D				
IIA/B-IIIA	11	6	1	
IIIA	$\frac{17}{17}$	$\frac{6}{6}$	$\frac{1}{11}$	
IIIB	2	1	3	
		p=0.82, FEP	p=0.06, FEP	
Horizontal/Straight-sided/Post-D				
IIA/B-IIIA	1	0	2	
IIIA	$\frac{23}{6}$	$\frac{11}{2}$	$\frac{7}{6}$	
IIIB				
		p=0.54, FEP	p=1.00, FEP	
Horizontal/Round-bottom/Pre-D				
IIA/B-IIIA	12	4	3	
IIIA	6	6	5	
IIIB	12	3	7	
		$\chi^2=3.18, NS$	$\chi^2=2.03, NS$	
Horizontal/Round-bottom/Post-D				
IIA/B-IIIA	0	1	0	
IIIA	$\frac{12}{18}$	$\frac{6}{6}$	$\frac{0}{15}$	
IIIB				
		p=0.31, FEP	p=0.006, FEP	
Vertical/Straight-sided/Pre-D				
IIA/B-IIIA	10	7	0	
IIIA	$\frac{16}{16}$	$\frac{7}{4}$	$\frac{0}{14}$	
IIIB	4	2	1	
		p=0.18, FEP	p=0.02, FEP	
Vertical/Straight-sided/Post-D				
IIA/B-IIIA	9	1	0	
IIIA	16	10	12	
IIIB	5	2	3	
		$\chi^2=2.78, NS$	$\chi^2=5.71, NS$	

Note. A 2-tailed region of rejection was adopted for the statistical tests used to compare Subgroup B (but not A) with NR(PC), as no prediction was made about the direction of the differences.

it was found that the former showed evidence of a significant delay in development on three of the seven tests: Horizontal/Straight-sided flask/Pre-D ($p = 0.02$); Horizontal/Round-bottomed flask/Post-D ($p = 0.002$); and Vertical/Straight-sided flask/Pre-D ($p = 0.002$) (Fisher exact probability test).

A similar analysis was carried out of the results of the projective tests (Table 3.12). It showed that boys in Subgroup A, but not Subgroup B, were significantly retarded in their acquisition of both left-right and above-below concepts, relative to the Performance control group. In contrast, the distribution of subjects on the further-nearer developmental scale was essentially the same for all three groups. (The pattern of results obtained when Subgroups A and B were compared with the Verbal control group was similar.) A further comparison (using the FEP test) showed that on the left-right and above-below scales there were fewer Subgroup A subjects at Stage III compared with the number of Subgroup B subjects, and correspondingly more at the lower stages ($p = 0.03$, and $p = 0.02$, respectively), but the difference did not reach significance in the case of the further-nearer relation ($p = 0.47$).

3.5 Discussion

The retarded readers were found to be at least as advanced in their conceptions of the horizontal and vertical as the normal readers, a result which is at variance with the findings of two previous investigations. However, when the performance of the retarded readers was examined more closely it was discovered that those who had a tendency to confuse the orientation of letters (Subgroup A) were more likely to be at the lower stages of the developmental scale than those who were free

Table 3.12 The comprehension of binary relations in projective space:
Distribution on the developmental scale of the normal
readers (Performance control) and retarded reader Subgroups
A (orientation errors present) and B (orientation errors
absent).

	Normal Readers (PC) (Groups I, II, and III)	Retarded Readers Subgroup A	Retarded Readers Subgroup B
<u>Left-right</u>			
Mean CA	10:4	10:1	10:4
Stage			
O-IB	4	5	1
II	$\frac{13}{11}$	$\frac{7}{0}$	$\frac{8}{5}$
III	$\frac{11}{2}$	$\frac{0}{1}$	$\frac{5}{1}$
Uncl.			
		p=0.009, FEP	p=1.00, FEP
<u>Above-below</u>			
Mean CA	10:3	10:0	10:3
Stage			
O-IB	1	1	1
IC	$\frac{13}{16}$	$\frac{10}{2}$	$\frac{5}{9}$
III	$\frac{16}{0}$	$\frac{2}{0}$	$\frac{9}{0}$
Uncl.			
		p=0.02, FEP	p=0.92, FEP
<u>Further-nearer</u>			
Mean CA	10:4	10:0	10:4
Stage			
O-IB	4	2	2
IC	$\frac{19}{6}$	$\frac{8}{2}$	$\frac{10}{1}$
III	$\frac{6}{1}$	$\frac{2}{1}$	$\frac{1}{2}$
Uncl.			
		p=0.57, FEP	p=0.57, FEP

Note: A 2-tailed region of rejection was adopted for the statistical tests used to compare Subgroup B (but not A) with NR(PC) as no prediction was made about the direction of the differences.

of such errors (Subgroup B), and this disparity reached significant proportions on three of the seven axes of reference tests. Notwithstanding its immaturity relative to Subgroup B, the performance of Subgroup A was still on a par with that of the normal readers.

The reason for the lack of agreement between these findings and those of earlier studies cannot be established with certainty. However, there is some evidence that the selection procedure used by Lovell et al. gave rise to a group of retarded readers whose non-verbal abilities were inferior to those of the controls. Although members of the two groups were individually matched in terms of their scores on a group test of non-verbal intelligence, when they were subsequently assessed on four WISC subtests - Vocabulary, Block Design, Coding, and Object Assembly - the retarded readers obtained a significantly lower mean score on all but the last. It will be recalled that in the Cambridge sample retarded readers were individually matched to members of the Performance control group on the basis of their Maxwell Performance Score, i.e., the sum of the scaled scores on Block Design and Object Assembly. If the same index were to be used in defining the non-verbal abilities of Lovell's subjects, then the retarded readers would turn out to be less able than the normal readers, and this disparity, rather than that in reading levels, could very well explain why one group was more advanced than the other in the acquisition of euclidean concepts. Amongst Cambridge retarded readers, the members of Subgroup B, who were more advanced in their conception of the horizontal and vertical than those of Subgroup A, also gained a higher mean score on the Block Design subtest, though the difference was not significant, a pattern of results which might be held to support the foregoing interpretation of Lovell et al.'s findings.

The slightly more advanced performance of the retarded readers on axes of reference tests was not maintained in the sphere of projective relations. Although the distribution of subjects on the developmental scales did not differ significantly from one group to the other, it was apparent that fewer retarded readers had achieved complete objectification of the concepts. Even so, almost all retarded readers (and all normal readers) were consistently successful in naming the left and right sides of the body, and this finding accords with the results of earlier studies (Coleman and Deutsch, 1964; Harris, 1957) which have shown that, although left-right confusion is fairly common in younger retarded readers, it is no longer in evidence at the age of nine years.

Despite the fact that the overall results in the two groups were more or less equivalent, when the levels of performance of the two subgroups of retarded readers were examined separately, it emerged that the subjects who had shown a tendency to confuse orientation were significantly delayed in the acquisition of the concepts of left-right and above-below, relative to the normal readers. However, in their understanding of the further-nearer concept both subgroups were at about the same stage of development as the normal readers. Not only did Subgroup A exhibit a delay in the development of projective and euclidean concepts, relative to Subgroup B, they also obtained markedly inferior scores on measures of reading accuracy, spelling and vocabulary.

A full assessment of these findings and their significance in relation to the hypotheses under examination will be undertaken in the concluding chapter.

Chapter 4

4.1 Introduction

On the basis of the theory advanced in Chapter 1, it was suggested that the egocentric frame of reference subserves the recognition or identification of a figure's orientation not by enabling the individual to perform explicit acts of referral, but rather through its effect on the phenomenal appearance of the figure. If the frame of reference is absent or poorly established one would expect the phenomenal appearance of a figure to be invariant with respect to orientation. Not only are judgments of orientation thereby rendered more difficult, but it also follows that complex mono-oriented figures (such as words and faces) should be no more difficult to recognize when they are inverted than when they are in the normal position. Reports by clinical investigators afford some support for this conclusion. For instance, Critchley (1970) reported that "When testing dyslexics as to their powers of silent or oral reading it is not infrequently found that the child performs no worse - sometimes indeed a little better - if the book is held upside down. This was so in Pflugfelder's patient, and it has been obvious in many dyslexics in my own series." (p.31). In the same work Critchley makes the observation that: "Very occasionally a young dyslexic may give evidence of what would appear to be a selective kind of inverted vision. This may be suggested by the manner in which they gaze at illustrations in a picture book, or by their habit of drawing in an upside-down fashion." (p.50). A similar phenomenon was noted by Tansley (1971) in describing a retarded reader who produced an accurate life-sized self-portrait - drawn upside-down.

The issue under consideration here is related to a more general one, namely, how the effect of spatial transformation on form recognition is modified as the child grows older. Studies conducted in the past have generated two opposing points of view, one (subscribed to by Goldstein (1965), Koehler (1940), Koffka (1931), Newhall (1937), Rice (1930), and Stern (1926), amongst others) in which the recognition of forms is said to be relatively independent of orientation in young children, but becoming more dependent with increasing age, and the other position (represented by Brooks and Goldstein (1963), Ghent (1960) and Hunton (1955)) in which recognition performance is thought to become less dependent on orientation with increasing age, that is to say, the inverted/upright recognition ratio¹ approaches unity with increasing age. Now the first of these points of view, when viewed in relation to the finding that some retarded readers are able to recognize inverted figures with the same ease as upright figures, is consistent with the supposition that a delay in maturation may, in some cases, be responsible for reading retardation. However, positive evidence for this hypothesis is lacking, for although form recognition under spatial transformation has been examined in a number of studies, such as those cited above, only two authors (Clay, 1970; Deich, 1971) have attempted to relate performance to different levels of reading ability, and in both cases the results were somewhat inconclusive.

Deich's aim was to determine whether developmental changes associated with the recognition of upright and inverted forms are related to (a) chronological age, (b) mental age, or (c) reading ability, or some combination of

¹ This ratio is defined as: (number of correct responses to inverted figures)/(number of correct responses to upright figures), or the equivalent in terms of error rate, response time (i.e., time elapsed in reading the list of words), or latency.

these factors. Her subjects were drawn from three different age ranges - approximate mean ages 8, 12, and 14 years - and each was sub-divided into two groups, one of average intelligence and the other of above average intelligence. Within each age range the members of the high IQ subgroup were also the more able readers.

The subjects' task was to read eight lists of 25 words each. Words in the lists varied in orientation (upright/inverted), length (three-letter/six-letter), and familiarity (familiar/unfamiliar), giving eight different combinations in all. Each subject was told that his aim was to read the list as fast as possible, and his time was measured by stopwatch. From the subjects' scores ratios were calculated giving the time to read upright lists versus the time to read inverted lists, for word lists varying in length and familiarity. These ratios were averaged within each age/intelligence subgroup.

The major finding was that reading inverted words became more difficult relative to reading upright words (i.e., the ratio referred to above decreased) with increasing age. As would be expected, the absolute difficulty of both upright and inverted lists decreased with age. Within age levels, the upright/inverted recognition ratio was lower for the high IQ group than for the average IQ group (and consequently lower for the more able readers than for the less able ones). Deich concludes that no single factor can account for the results. Groups of equivalent IQ or CA exhibited different recognition ratios, so that MA and/or reading level could be considered factors, but the effect was also present when MAs and reading levels happened to be matched, as occurred in the case of the 12-year-olds of above average intelligence and the 14-year-olds of average intelligence. Although Deich's finding and Critchley's observation apply

to different regions of the spectrum of reading ability, they are, nevertheless, similar (disregarding for the moment the possibility that the effects of MA and reading ability were confounded in the former study), insofar as the change in recognition ratio with level of reading ability is in the same direction in both cases.

With a similar object in view, Clay carried out a longitudinal study to examine what effect inversion and reversal of text has on children's reading performance at age 5:6, 6:0, 7:0, and 8:0. Her method was to present words one at a time in three series, viz., upright, inverted, and reversed, each of which contained 15 words. In contrast to Deich's procedure the child's performance was not timed; instead the number of words read correctly in each orientation was noted. At age 6:0 children were sub-divided into four ability groups (high (H), high-middle (HM), low-middle (LM), and low (L)) on the basis of their performance on a word reading test.

Clay maintains that there was an increasing effect of inversion on reading performance with increasing age and that it reached a significant level for the complete sample and also for each of the four reading ability subgroups. However, it is difficult to see how this result could have been obtained unless the scores were analyzed incorrectly, for the reported trend is not apparent from the tabulated data. In fact, it is evident from Table 1 of Clay's paper that the ratios of mean scores obtained by the total sample on inverted and upright lists were virtually constant across the whole age range (0.76 at 5:6, 0.80 at 6:0, 0.79 at 7:0, and 0.77 at 8:0).¹ Had the test for trend been based on the

¹ It is the usual practice to calculate the mean of subjects' ratios, rather than the ratio of their mean scores, but as the complete data could not be retrieved from Clay's paper it was necessary to adopt the latter method. In general, the two methods of calculation do not lead to the same result, although it is unlikely that there would be a significant age-related trend in the magnitude of subjects' ratios without it being possible to detect a similar trend in the ratio of their mean scores.

difference between scores rather than their ratio then one can well imagine that a significant result would have been obtained, but Clay was apparently aware that it is not legitimate to compare the relative difficulty of upright and inverted lists in this way, particularly when the subsequent analysis involves the comparison of difference scores which have been derived from pairs of absolute values of different orders of magnitude. So, although some of her tabulated results are presented in the form of difference scores, Clay stresses that these did not form the basis of her statistical tests. However, in testing the hypothesis that, with increasing age, there is an increasing effect of change in orientation on the child's word reading performance, Clay neglects to specify exactly what measure was used, merely stating that "A monotonic test of the increasing trend for scores to differ recorded change at the coarse level of plus or minus, taking every child's set of scores into account (Table 2)." (p.300). Far from elucidating the matter this statement only raises further questions about Clay's procedure, for in applying the monotonic trend test it is usual to rank subjects' scores under the various conditions and then correlate the ranks with the order of conditions (in this case, the four age levels). The monotonic trend test is equivalent to a sign test for correlated samples if and only if there are two conditions, which was not the case in Clay's experiment.

Clay carried out a further analysis, employing the Wilcoxon matched-pairs, signed-ranks, test, to determine the significance of the difference between scores on the inverted and upright lists (and likewise for scores on the reversed and upright lists), for each age/reading ability subgroup. The levels at which these differences were significant were assumed to indicate the extent to which reading performance was affected by inversion

or reversal of text. Clay interprets the results as showing that whereas, from the age of 5:6 onwards, the high ability group exhibited a significant difference between performance on the upright list and performance on the inverted list, the low ability group did not do so until 8:0. However, the pattern of results was not as well-defined as Clay's concluding statement implies insofar as at age 5:6 the number of low ability subjects who obtained non-zero scores was not large enough to permit the statistical test to be applied, while at age 6:0 the difference between this group's scores was significant at the .025 level, though not at the .005 level, which was the value used elsewhere to determine whether the null hypothesis should be rejected.

A further point to consider in assessing these findings is that the low attainment group had a mean IQ some 17 points lower than that of the high attainment group, although Clay considered that this disparity had not significantly influenced the results. Her reason for doubting whether IQ has an effect was based on two observations. The first was that, whereas the LM and L groups were quite closely matched for IQ, they differed quite markedly, throughout the age range, in the extent to which upright scores exceeded inverted scores. Secondly, whereas there was a significant difference in IQ between the HM and LM groups, inversion had much the same effect on recognition in both groups. Nevertheless, it was felt after reviewing the work of Clay and Deich that the findings required verification under more rigorous control conditions before their hypotheses could be accepted with complete confidence. The experiment described in the next section of this chapter is designed to establish whether the results obtained by Deich and Clay hold true for the matched groups of retarded and normal readers

in the Cambridge sample. Assuming that Critchley's observation is confirmed and that word recognition performance is found to be less dependent on orientation in retarded than in normal readers, it is then proposed to establish whether this effect is peculiar to text, or whether it reflects a basic property of the visual system in retarded readers. If the latter is the case, then one would expect to obtain similar results with other classes of visual stimuli. The recognition experiments described in section 4.3 are designed to ascertain whether the same effect is obtained when the stimuli are photographs of human faces. Finally, in Section 4.4, the findings of Sections 4.2 and 4.3 are examined more closely to determine whether there is any association between the tendency in some retarded readers to produce orientation errors and their ability to recognize words and faces under spatial transformation.

4.2 The effect of spatial transformation on the recognition of words.

Procedure

The materials consisted of six lists, each containing 20 three-letter words. The lists differed from each other in orientation (upright (U), inverted (I), and reversed (R)) and in the degree of word familiarity (familiar (F) and unfamiliar(NF)). In addition there was a practice list of five words for each orientation/familiarity combination, making a total of 75 familiar words and 75 unfamiliar words. It was necessary to take the familiar words from two sources as the first source consulted contained insufficient words of the required type. Thus 43 were taken from the list compiled by Edwards and Gibbon (1973), a selection which comprises the 250 most common

words (all lengths) found in the writing of children aged 7+. The remaining 32 were from the Thorndike and Lorge (1944) word count, the selection being restricted to words of frequency AA or A in the G column, or frequency M in the J column. Unfamiliar words were taken from the J column of the Thorndike and Lorge word count, but including only those which had a frequency of less than 50 per 4.5 million words.¹

Using Letraset (20 pt lower case Futura Bold, normal and reversed) the words were set out in a column on ruled paper with the start of each word next to a faint blue margin. The six 20-word lists for each orientation/familiarity combination were mounted on separate cards (2.75" x 10.50"). The familiar and unfamiliar practice words were arranged on two other cards, each having the words arranged by orientation in three columns of five (upright, inverted, and reversed).

Following untimed practice subjects were asked to read through the 20-word lists as fast as they could, and their performance was timed by stopwatch and recorded on tape. No precise method of controlling the time spent on each word was used, but approximately five seconds were allowed for words which were refused or misread the first time, before

¹ Words containing the letters b, d, p, and q were not included in either the familiar or unfamiliar lists. The reason for this restriction was that these four letters share the same form (as do the pairs u-n and m-w, though they were not excluded), and it is necessary to perform an act of mental rotation in order to identify them when inverted or reversed. However, in the case of letters which do not share their form with others such a correction is not necessary, although some individuals might find that it assisted identification in the event that there is a marked alteration in the phenomenal form of letters when inverted. Since the purpose of the experiment was to determine the extent to which the phenomenal form of letters and words is affected by disorientation, rather than to examine subjects' ability to perform corrective rotations, it was thought that reducing the number of instances where the latter strategy had to be employed would help to ensure that the results actually related to the effect under investigation. Of course, there is no guarantee that children do not attempt to mentally rotate even those letters which in theory can be identified without the aid of corrective transformations.

reading the word to the child and proceeding to the next one. All children were presented with the familiar lists before the unfamiliar ones, but within each of these categories the order of presentation of the three orientations was varied from child to child in order to counterbalance, so far as possible, any order effects which might otherwise have been present. The taped records were subsequently transcribed and scored.

Results

For each list two measures of performance were obtained: (1) the time taken to read the list, and (2) the number of words read correctly at the first attempt. Using the time scores (1), upright (U)/inverted (I) recognition ratios (T-ratios) were calculated for each subject under each condition (familiar and unfamiliar words). Similarly, using the number of words per list which were read correctly (2), inverted (I)/upright (U) recognition ratios (N-ratios) were calculated for each subject under each condition. N-ratios could have been defined as U/I ratios, but the resulting values would have occupied a different interval of the measurement scale, i.e., from 100% upwards, instead of 0-100%, as was the case for the inverse. There would have been no objection to defining N-ratios in this way, except it was found that when the results were subjected to an analysis of variance U/I ratios gave rise to a somewhat greater degree of heterogeneity in the sources of variation.

Both sets of ratios were averaged over the group of retarded readers and the two control groups, with separate analyses for each of the three age ranges. The results are shown in Table 4.1, together with the mean times and the mean number of correct words for each orientation/familiarity

Table 4.1 Word recognition under spatial transformation in retarded readers (RR) and normal readers (NR(VC): Verbal control; NR(PC): Performance control). (Group I: N = 8; Group II: N = 9; Group III: N = 8.)

	Group I			Group II			Group III		
	RR	NR (VC)	NR (PC)	RR	NR (VC)	NR (PC)	RR	NR (VC)	NR (PC)
Mean CA	9:3	9:1	9:2	9:8	9:6	9:7	11:4	11:9	11:
<u>Mean list times (secs.)</u>									
Familiar words									
Upright	26.6	13.6	14.6	23.0	14.7	13.1	26.8	12.6	10.
Inverted	80.6	65.3	59.9	77.7	48.6	51.4	79.9	41.1	35.
Reversed	94.8	71.8	62.8	78.9	60.2	54.6	80.1	35.6	34.
Unfamiliar words									
Upright	102.3	35.8	34.8	74.8	23.3	24.7	82.0	22.1	16.
Inverted	128.9	104.6	95.5	132.2	81.3	85.1	118.5	65.6	63.
Reversed	137.5	100.8	99.8	130.1	87.9	86.0	124.4	63.8	54.
<u>Mean T-ratios (%)</u>									
Familiar words									
U/I	34.4	22.3	26.0	31.7	35.1	30.2	33.9	36.4	34.
U/R	29.0	21.0	25.3	30.5	26.3	27.9	38.6	36.8	35.
Unfamiliar words									
U/I	79.4	33.7	35.0	55.8	32.1	29.8	64.9	36.2	27.
U/R	76.0	35.3	34.5	59.5	27.6	29.6	65.5	33.4	31.
<u>Mean no. correct/list</u>									
Familiar words									
Upright	18.1	19.8	19.9	18.4	19.8	20.0	18.4	19.9	20.
Inverted	13.4	16.4	17.0	13.0	17.4	17.3	13.8	19.1	18.
Reversed	13.5	15.9	16.8	13.3	17.3	17.9	13.0	19.3	19.
Unfamiliar words									
Upright	11.4	17.6	17.4	10.7	18.3	17.6	11.6	18.3	18.
Inverted	7.9	12.0	12.8	7.4	14.4	13.9	7.4	16.9	15.
Reversed	9.1	14.8	14.4	7.4	13.6	14.0	9.4	16.4	17.
<u>Mean N-ratios (%)</u>									
Familiar words									
I/U	73.2	83.0	85.6	70.6	88.3	86.7	74.1	96.2	94
R/U	74.0	80.5	84.4	73.0	87.7	89.4	70.7	96.9	97
Unfamiliar words									
I/U	70.8	68.4	73.3	80.8	78.8	80.1	67.5	92.9	86
R/U	77.2	83.4	83.3	72.3	73.9	80.8	90.8	89.8	96

combination. The scores obtained by the retarded readers and the Verbal control group were analyzed by means of a 2 x 2 x 2 (age x reading ability x word familiarity) analysis of variance, with repeated measures on the factor of word familiarity. This test was performed on four dependent variables: U/I T-ratios, I/U N-ratios, U/R T-ratios, and R/U N-ratios. Inspection of Table 4.1 shows that the mean scores of the Performance control group did not differ appreciably from those of the Verbal controls, and it is likely that the analysis would have yielded similar results had it involved the former group rather than the latter.

It will be recalled that, for reasons given in Chapter 2, the recruitment schedule resulted in Group II being much closer in age to Group I than to Group III, and it was therefore decided to limit the age factor to the two most widely spaced levels - Group I and Group III. Two Group I retarded readers could not be included in the analysis because they had found the inverted and reversed lists too difficult to attempt. A third retarded reader from Group I was excluded because, although he completed all three unfamiliar lists, his scores (U = 1, I = 1, R = 0) were too low to be analyzed. Two retarded readers in Group III also failed to complete the test on account of the excessive difficulty presented by both familiar and unfamiliar lists. Of course, it was also necessary to exclude the respective controls of all the aforementioned retarded readers. Thus, for the purposes of the analysis which is about to be described, Groups I and III each comprised eight retarded and eight normal readers.

Considering first of all the analysis performed on the U/I T-ratios, significant main effects were found for reading ability ($F = 25.16$, $df = 1/28$, $p < 0.01$), and word familiarity ($F = 45.68$, $df = 1/28$, $p < 0.01$), but

not for age. In addition, there was a significant interaction between reading ability and word familiarity ($F = 25.05$, $df = 1/28$, $p < 0.01$). The effects were such that, in terms of reading speed, the retarded readers would appear to be less affected by inversion of text than normal readers (Fig. 4.1 (a)), though the difference between the groups was much more pronounced when the words were unfamiliar than when they were familiar, hence the interaction (Fig. 4.1 (c)). Moreover, the high T-ratios obtained by the retarded readers on unfamiliar lists can be attributed, in large measure, to the disproportionately longer time they took in reading the upright lists of unfamiliar words, rather than a relative reduction in the time they took to read inverted lists. (The retarded readers took 1.54 times as long, on average, to read inverted lists of unfamiliar words as they did inverted lists of familiar words. Similarly, the normal readers took 1.60 times as long to read inverted lists of unfamiliar words as they did to read inverted lists of familiar words, and 2.20 times as long to read upright lists of unfamiliar words as they did to read upright lists of familiar words. In contrast, the retarded readers took 3.45 times as long to read upright lists of unfamiliar words as they did upright lists of familiar words.)

The analysis of variance performed on the R/U T-ratios revealed a similar pattern of results, with significant main effects of reading ability ($F = 20.49$, $df = 1/28$, $p < 0.01$), and word familiarity ($F = 32.58$, $df = 1/28$, $p < 0.01$), and a significant interaction between reading ability and word familiarity ($F = 17.98$, $df = 1/28$, $p < 0.01$). Again, the reason for the high T-ratios obtained by retarded readers on unfamiliar lists lay in the disproportionately long time taken to read upright lists of unfamiliar words. The unfamiliar/familiar ratios for upright words were,

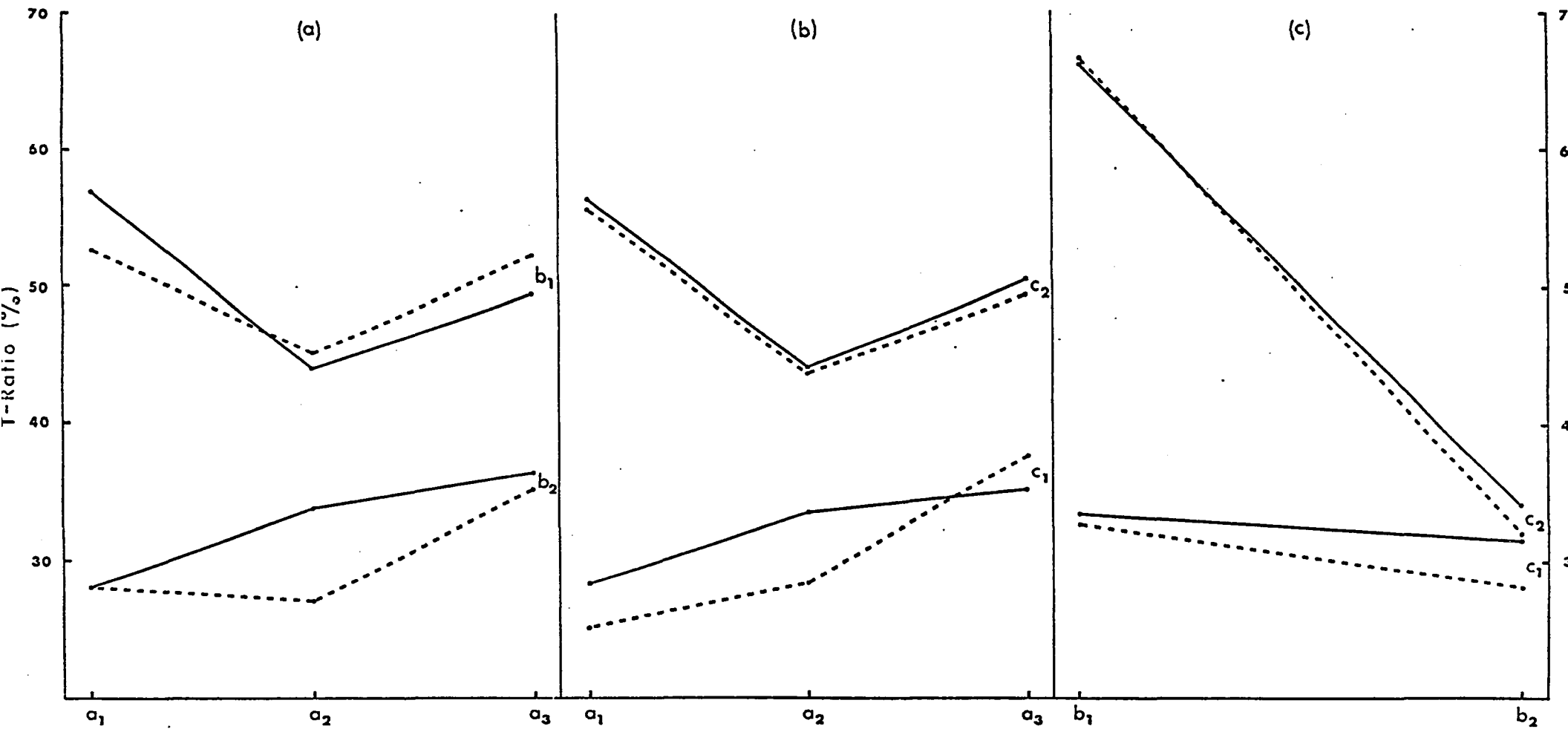
Fig. 4.1. Profile of mean scores showing effect of age (A), reading level (B), and word familiarity (C) on U/I and U/R T-ratios.

Key: Factor A: a_1 - Group I
 a_2 - Group II
 a_3 - Group III

Factor B: b_1 - Retarded readers
 b_2 - Normal readers

Factor C: c_1 - Familiar words
 c_2 - Unfamiliar words

— U/I
 - - - U/R



of course, identical with those obtaining in the case of the I/U comparison, being based on the same mean times. Moreover, the unfamiliar/familiar ratios for reversed words were almost exactly the same as in the case of inverted words: 1.50 for the retarded readers, and 1.58 for the normal readers.

The results of the T-ratio (U/I) analysis described above do not altogether bear out the conclusions reached by Deich in her study of average and above average readers. It will be recalled that, for her subjects, reading inverted words became more difficult in relation to reading upright words, with increasing age. Comparing Groups I and III, a similar, though non-significant, effect was discernible in the Cambridge data, but it was exhibited only by the retarded readers, there being an equal and opposite tendency on the part of normal readers for inverted text to become easier with increasing age (Fig. 4.1 (a)). On the other hand, the results do suggest that the effect of reading level found by Deich may be present even when IQ is held constant, although the fact that it was attributable to the disproportionate degree of difficulty experienced by retarded readers on upright lists of unfamiliar words tends to reduce the import of the finding for the hypothesis under investigation. It cannot be determined whether similar underlying processes were at work in Deich's experiment as there was no interaction within grades between IQ (or reading ability) and word familiarity.

The foregoing analysis was repeated for I/U N-ratios. The effect of reading level again proved to be significant ($F = 12.31$, $df = 1/28$, $p < 0.01$), but its direction appeared to be just the opposite of that suggested by the T-ratio analysis, in that it was the normal readers rather than the retarded readers, whose performance was least affected by

inversion of text. The reasons for the apparent contradiction between the two sets of data will be discussed in due course, but before doing so the results of the N-ratio analysis will be described in full. As shown in Fig. 4.2 (a), it was primarily in Group III that the effect of reading level manifested itself, although the interaction between age and reading level failed to reach a significant level ($F = 6.57$, $df = 1/28$, $0.01 < p < 0.05$). (The performance of Group III normal readers on the upright familiar lists (mean score = 19.9) was almost free of error, and even though Group I normal readers achieved a score (19.1) which was not appreciably lower, it is possible that a ceiling effect contributed a spurious element to the high N-ratios obtained by the former group.) The effect of age on the magnitude of N-ratios was not significant ($F = 5.12$, $df = 1/28$, $0.01 < p < 0.05$),¹ and neither was the

¹ One of the assumptions that must be satisfied if the computed F ratios are actually to conform to an F distribution is that their denominators should be homogeneous with respect to the constituent sources of variation (Winer, 1970). The between-subjects error term meets this condition provided that the statistic:

$$F_{\max} = \frac{\text{maximum (SS}_{\text{subj. w. groups}})}{\text{minimum (SS}_{\text{subj. w. groups}})}$$

(i.e., the ratio of the largest source of variation to the smallest) does not exceed a certain critical value denoted by $F_{\max(1-\alpha)}(ab, n-1)$, where a is the number of levels of factor A, b the number of levels of factor B (A and B are the between-subjects factors), and n is the number of subjects in each group. In this case the critical value of F_{\max} is either $F_{0.95}(4, 7) = 8.44$, or $F_{0.99}(4, 7) = 14.5$, depending on whether the significance level adopted is 0.05 or 0.01.

Similarly, the within subjects error term meets the aforementioned condition provided that:

$$F_{\max} = \frac{\text{maximum (SS}_{\text{C x subj. w. groups}})}{\text{minimum (SS}_{\text{C x subj. w. groups}})}$$

is less than $F_{\max(1-\alpha)}(ab, (n-1)(c-1))$ a statistic which, in the present application, yields the same values as in the between-subjects case. F ratios were computed for each of the four analyses of variance performed in this experiment, with the following results:

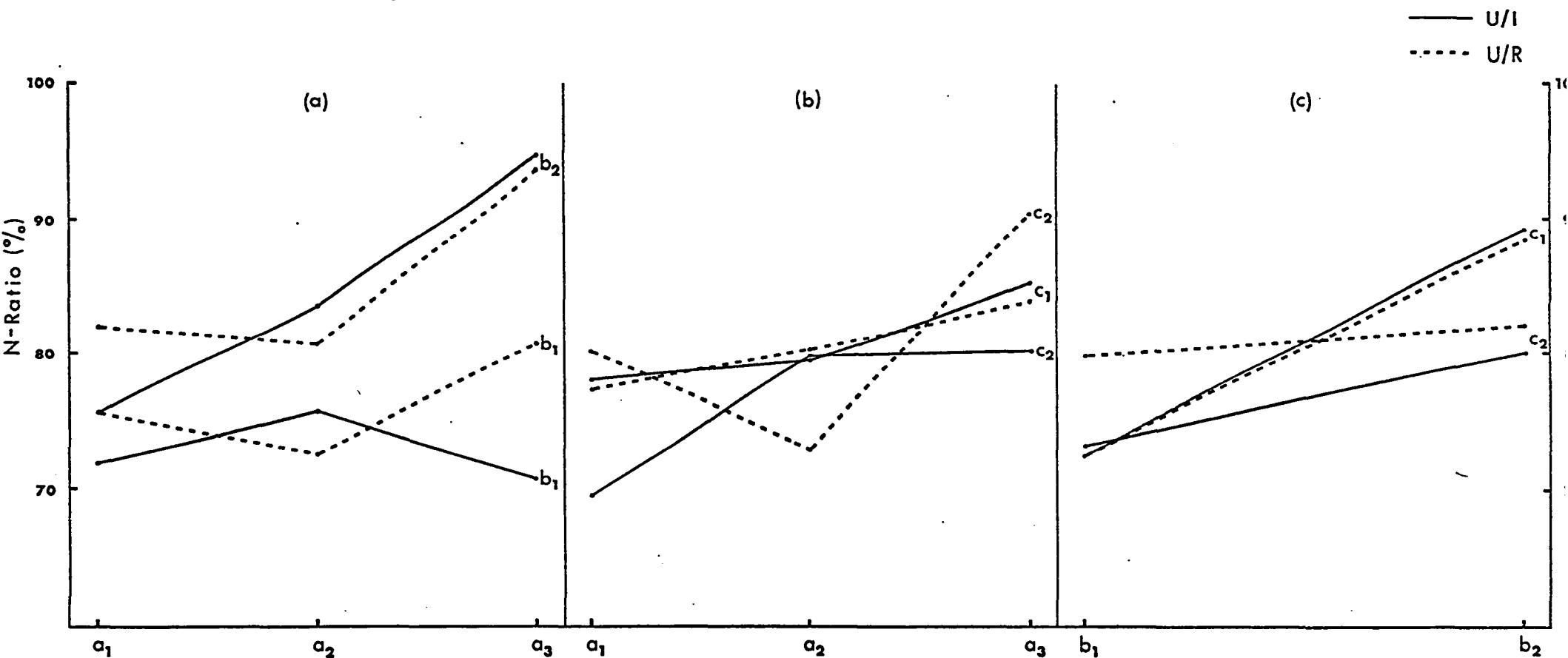
(continued at foot of p.153)

Fig. 4.2. Profile of mean scores, showing effect of age (A), reading level (B), and word familiarity (C) on I/U and R/U N-ratios.

Key: Factor A: a_1 - Group I
 a_2 - Group II
 a_3 - Group III

Factor B: b_1 - Retarded readers
 b_2 - Normal readers

Factor C: c_1 - Familiar words
 c_2 - Unfamiliar words



effect of word familiarity, findings which are in accord with the results of the T-ratio analysis only in respect of the first factor (age).

Though the effect of word familiarity did not reach significance, it was the lists of familiar words which yielded the higher mean N-ratios (Fig. 4.2 (c)), whereas in the T-ratio analysis it was the unfamiliar lists which gave rise to the higher values (Fig. 4.1 (c)).

The U/R N-ratio analysis failed to reveal any significant main effects or interactions, an outcome which was due not so much to the convergence (relative to the U/I data) of the means of the dependent variable under the various "treatment combinations" but rather to the increased magnitude of the between-subjects and within-subjects error terms.

It is clear from Figs. 4.1 and 4.2 that the effects of the three factors and their interactions were the same for both U/I and U/R T-ratios, but the same was not true for the corresponding sets of N-ratios. The disparity between mean I/U and R/U N-ratios is primarily attributable to differences in performance on lists of unfamiliar words. Thus, for all combinations of levels of age and reading ability, reversal of text had a

Note continued from foot of previous page:

Dependent Variable	F_{\max}	
	Between-Ss error term	Within-Ss error term
U/I T-ratio	6.53	2.83
U/R T-ratio	11.57	6.79
I/U N-ratio	4.35	11.74
R/U N-ratio	5.21	9.48

Thus, in most instances main effects and interactions could safely have been considered significant at the 0.05 level, since F_{\max} is less than 8.44, but in a few cases the latter condition fails to be satisfied. Since it was thought desirable to adopt the same significance level in testing for all main effects and interactions, and in view of the fact that in all cases F_{\max} is less than $F_{0.99}(4, 7) = 14.5$, a value of $p=0.01$ was adopted.

similar effect to inversion on the number of familiar words which were read correctly, but on lists containing unfamiliar words the former transformation had a much less pronounced effect than the latter.

Returning to the question of why the factor of reading level has an effect on U/I T-ratios which is directly opposite to its effect on I/U N-ratios, in order to explain this finding it is necessary to consider the nature of the relationship between the number of words read correctly (n) and the time taken to read the list (t). Naturally, the form of this relationship varied from one orientation/familiarity condition to another, but a plot of n versus t for the retarded readers and the normal readers under each condition showed that for values of t in the range from approximately 10 to 200 seconds the regression of n on t could be reasonably well described by a linear function of the form:

$$n = c_0 + c_1 t.$$

The values of the constants c_0 and c_1 were computed for the retarded readers ($N = 16$) and the normal readers ($N = 16$) from Groups I and III combined, under each orientation/familiarity condition, with the results shown in Table 4.2. Except in the case of normal readers under the upright/familiar condition, the number of correct words per list, n , is a decreasing function of list time, t , the general form of the relationship being shown in Fig. 4.3. The significance of this function will become clear in the course of the proof that follows.

The second point which has to be taken into consideration in elucidating the relation between T-ratios and N-ratios, and one which applies to retarded and normal readers alike, is that in general high T-ratios are the quotients of high list times and low T-ratios are the quotients of low list times, since list times increase as word familiarity

Table 4.2 Linear regression equations expressing the relationship between number of words read correctly (n) and time to read list (t) under each orientation/familiarity condition, for the retarded and normal (Verbal control) readers of Groups I and III.

Orientation/familiarity Combination	Regression Equation	Standard Error of Estimate
Retarded Readers		
Upright/Familiar (U/F)	$n = 20.71 - 0.09t$	0.82
Upright/Unfamiliar (U/NF)	$n = 15.81 - 0.05t$	2.96
Inverted/Familiar (I/F)	$n = 19.29 - 0.07t$	2.72
Inverted/Unfamiliar (I/NF)	$n = 12.45 - 0.04t$	1.76
Normal Readers		
Upright/Familiar (U/F)	$n = 19.78 + 0.002t$	0.42
Upright/Unfamiliar (U/NF)	$n = 19.35 - 0.05t$	1.10
Inverted/Familiar (I/F)	$n = 21.85 - 0.08t$	1.34
Inverted/Unfamiliar (I/NF)	$n = 21.35 - 0.08t$	2.36

Table 4.3 Mean list times obtained by Groups I and III (retarded and normal readers combined) under each orientation/familiarity combination.

Orientation/Familiarity Combination	Mean List Time (secs.)
Upright/Familiar (U/F)	19.9 ($t_{U/F}$)
Upright/Unfamiliar (U/NF)	66.7 ($t_{U/NF}$)
Inverted/Familiar (I/F)	60.3 ($t_{I/F}$)
Inverted/Unfamiliar (I/NF)	104.4 ($t_{I/NF}$)

decreases, and T-ratios do so as well (Fig. 4.1 (b)). Now the mean list times actually obtained by the retarded and normal readers of Groups I and III combined under the four orientation/familiarity conditions are shown in Table 4.3. It is evident that:

$$t_{I/F} - t_{U/F} = 46.8 \doteq t_{I/NF} - t_{U/NF} = 44.1,$$

and for the purposes of the proof that follows, the situation may be idealized to some extent by putting $t_{I/F} - t_{U/F} = t_{I/NF} - t_{U/NF} = \Delta t$. The problem then reduces to one of demonstrating that n_I/n_U must decrease as t_U and t_I increase with Δt maintained constant (Fig. 4.3).

Now,

$$t_U/t_I = (t_I - \Delta t)/t_I = 1 - \Delta t/t_I$$

If a further approximation is made for the purposes of simplifying the proof, namely that c_1 , the coefficient of t in the expression for n , has the same value, $-c_1'$, where c_1' is a positive number, for normal and retarded readers under all conditions, then in general:

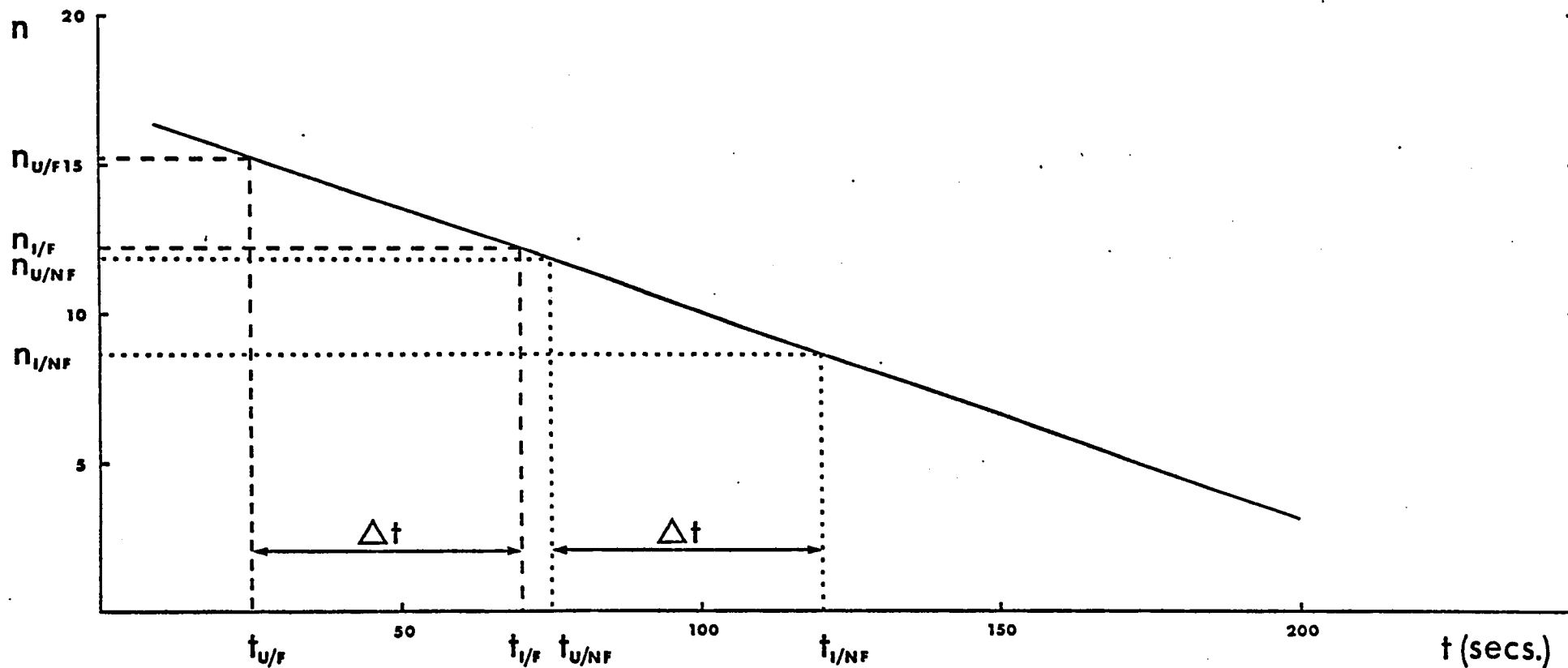
$$n_U - n_I = c_1' \Delta t,$$

$$\begin{aligned} \text{and } n_I/n_U &= n_I/(n_I + c_1' \Delta t) \\ &= 1/(1 + c_1' \Delta t/n_I). \end{aligned}$$

As t_I increases, $t_U/t_I = 1 - \Delta t/t_I$ also increases, but n_I decreases, because of the form of the function shown in Fig. 4.3. Therefore $n_I/n_U = 1/(1 + c_1' \Delta t/n_I)$ also decreases, since $c_1' \Delta t$ is constant.

If Δt is not constant, but decreases with increasing t , as was actually the case in this experiment, then t_U/t_I increases by a greater amount than it otherwise would, whereas n_I/n_U decreases by a smaller amount. The change in n_I/n_U will not be reversed (i.e., n_I/n_U will not become an increasing function of t_U/t_I) provided that Δt does not change at a faster rate than n_I , and this condition was far from being violated in the present situation.

Fig. 4.3. The general form of the function: $n = c_0 + c_1 t$, showing the effect of an increase in t_U and t_I (with $t_I - t_U = t$ maintained constant) on the corresponding values of n . (To illustrate the proof in the text, where $t_{I/NF} - t_{U/NF} = t_{I/F} - t_{U/F} = t$, $t_{U/F}$, $t_{I/F}$, $t_{U/NF}$, and $t_{I/NF}$ have been given slightly different values from the ones actually obtaining in the experiment.)



It is more complicated to assess how the relationship between T-ratios and N-ratios which has been described would be modified by the fact that the coefficients c_0 and c_1 differ from one condition to another, but in the situation under consideration it is not believed that a more precise analysis, based on the functions obtained for each condition (Table 4.2), would have led to a different conclusion.

In view of the inverse relationship between T-ratios and N-ratios and the lack of any obvious grounds for giving preference to one variable over the other, it is difficult to see how one can arrive at an unambiguous interpretation of the results. There are situations where one type of ratio would be the obvious choice. For instance, if the experiment had involved adult subjects drawn from the average to above average range of reading ability, then it is likely that the mean number of correct words per list would have approached 100% under all conditions, so that T-ratios would have been the natural choice for an index of reading difficulty under spatial transformation. On the other hand, one can also envisage a modification in the method whereby words are presented one at a time for a fixed period in each condition. In these circumstances T-ratios could not assume any value other than 100%, and N-ratios would necessarily form the basis of the analysis. In the present study the design was such that neither of the ratios stands out as the natural candidate for an index of reading difficulty under spatial transformation. However, as will be shown below, the data may be analyzed in a way which obviates the necessity of choosing between N-ratios and T-ratios.

The analysis which is about to be described arose out of an attempt to resolve a further difficulty which presented itself in the course of

interpreting the results. An examination of the effect of word familiarity on N-ratios and T-ratios prompted the realization that, although the specification of a word's familiarity in terms of its frequency of occurrence in text provides an objective measure of the parameter, the familiar words, in their orthographic aspect, are much less familiar to the retarded readers than they are to the normal readers, and the same is true of the unfamiliar words. Thus, in this application, it is probably more appropriate to specify the familiarity of a word in terms of the ease with which it can be read. The crucial test of the hypothesis under consideration would then be to compare retarded and normal readers' ratios under conditions in which either the two numerators (in the case of T-ratios) or the two denominators (in the case of N-ratios) are of comparable magnitude, thus ensuring that the respective upright lists present the same degree of difficulty (defined in terms of either time elapsed or number of words read correctly) to both the retarded and normal readers. It so happens that the requisite conditions are provided by the retarded readers' performance on the list of familiar words and the normal readers' performance on the list of unfamiliar words. Table 4.4 shows the mean numbers of correct words per list and the mean list times for the retarded readers (N = 16) and the normal readers (N = 16) of Groups I and III combined, under each condition. In terms of the former measure the performance of the normal readers on the upright list of unfamiliar words (mean score = 17.9) was not significantly different from the mean score (18.3) obtained by the retarded readers on the upright lists of familiar words (t test, with paired observations: $t = -0.60$, $df = 15$). Looking next at performance on the inverted lists, the normal readers obtained a somewhat higher

Table 4.4 Word recognition under spatial transformation: Mean number correct and mean list time for retarded readers (N = 16) and normal readers (Verbal control) (N = 16), of Groups I and III combined.

Orientation/ Familiarity Combination	Groups I and III							
	RR				NR(VC)			
	No. Correct		List Time		No. Correct		List Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
U/F	18.3	1.4	26.7	13.0	19.8	0.4	13.1	3.5
U/NF	11.5	3.8	92.1	52.7	17.9	1.3	28.9	14.9
I/F	13.6	3.3	80.3	29.2	17.8	2.1	53.2	21.7
I/NF	7.6	2.8	123.7	53.7	14.4	3.4	85.1	31.2
R/F	13.3	4.0	87.4	37.0	17.6	2.5	53.7	23.0
R/NF	9.3	3.5	130.9	59.5	15.6	2.9	84.8	33.8

Table 4.5 Word recognition under spatial transformation: A comparison of the performance of Group II retarded readers (N = 9) and normal readers (Verbal control), (N = 9), on lists which are equivalent in terms of orthographic familiarity.

Variable	Group II					
	Performance of RR on F lists		Performance of NR(VC) on NF lists		t test	
	Mean	SD	Mean	SD	Value	Sig. Level
<u>No. of correct words:</u>						
U List	18.4	2.1	18.3	0.9	0.18	NS
I List	13.0	2.8	14.4	1.9	-1.40	NS
R List	13.3	3.9	13.6	1.9	-0.15	NS
<u>N-ratio:</u>						
I/U (%)	70.6	13.7	78.8	9.9	-1.55	NS
R/U (%)	73.0	23.5	73.9	9.7	-0.10	NS
<u>Elapsed time:</u>						
U List	23.0	11.7	23.3	7.0	-0.09	NS
I List	77.7	38.0	81.3	27.6	-0.26	NS
R List	78.9	32.0	87.9	29.1	-0.67	NS
<u>T-ratio:</u>						
U/I (%)	31.7	12.7	32.1	15.0	-0.05	NS
U/R (%)	30.5	13.7	27.6	6.5	0.54	NS

mean score (14.4) on the list of unfamiliar words than did the retarded readers on the list of familiar words (mean score = 13.6), a difference which, though not statistically significant ($t = 0.76$, $df = 15$), tends to suggest that it is the normal readers, rather than the retarded readers, whose performance is least affected by inversion of text. In view of these figures, one would expect to find fairly close agreement between the two groups' N-ratios. In fact, the mean N-ratio obtained by the normal readers on unfamiliar lists was 80.6% (see Fig. 4.2 (c)), and when this figure was compared with the mean of 73.6% obtained by retarded readers on familiar lists, it was not found to be significantly different ($t = -1.24$, $df = 15$). An analysis of time scores revealed a similar kind of picture. The normal readers' performance on unfamiliar words was not significantly different from the retarded readers' performance on familiar words, a finding which applied to both upright lists ($t = 0.44$, $df = 15$) and inverted lists ($t = 0.41$, $df = 15$). The corresponding mean T-ratios were 35.0% and 34.2% for the normal and retarded readers respectively, the difference again being non-significant ($t = -0.20$, $df = 15$).

The effect of reversal on retarded readers' performance was also found to be comparable to its effect on normal readers' performance when the word lists presented to the two groups were equated for orthographic familiarity. The relevant data for the upright lists were presented above. With regard to the number of reversed words read correctly, the normal readers had more success on the unfamiliar list (mean score = 15.6) than did the retarded readers on the familiar list (mean score = 13.3), though the difference did not reach a significant level ($t = 1.72$, $df = 15$). Under the same conditions the time scores obtained by the normal readers and retarded readers (see Table 4.4) were virtually identical ($t = -0.19$,

df = 15). As a result of their inferior performance on the upright list and their superior performance on the inverted list the normal readers' mean N-ratio (86.6%) turned out to be significantly higher than that of the retarded readers (72.3%), ($t = 2.14$, $df = 15$, $p < 0.05$), though in terms of T-ratios the two groups were closely matched (normal readers: $T = 34.3\%$; retarded readers: $T = 33.8\%$; $t = 0.09$, $df = 15$).

So far, no reference has been made to the results obtained by Group II. In fact this Group occupied a somewhat anomalous position between Group I and Group III, in that their N-ratios most closely resembled those of Group I, while their T-ratios were more similar to those of Group III (Table 4.1, Figs. 4.1 and 4.2). Nevertheless, their results conformed with those of the other two Groups, insofar as the normal readers' performance was not degraded to a greater extent than the retarded readers' when words were inverted or reversed under conditions where the upright lists presented the same degree of orthographic familiarity to both groups. This conclusion is based on the figures shown in Table 4.5.

4.3 The effect of inversion on the recognition of faces.

Introduction

The experiment described in this Section was originally designed to establish whether the relative facility which retarded readers were presumed to exhibit in the recognition of inverted text was an expression of a general property of the perceptual system. However, the fact that the original presumption was shown to be false considerably reduces the likelihood that the effect holds true for other types of stimulus.

Even so, the proposed experiment on the recognition of faces is not altogether superfluous, since it will still serve to verify that the finding is not peculiar to text.

A certain amount of work on age-related changes in children's recognition of inverted faces has been reported by other authors, but so far the issue does not appear to have been examined in relation to different levels of reading ability.

Brooks and Goldstein (1963) set out to verify the frequently encountered claim that young children can recognize inverted pictures as easily as upright ones. They did so by examining the ability of 3-14-year-old children to recognize black and white photographs of their classmates which were presented first in their normal orientation and then, a week later, in an inverted position, the pictures used in the second series being limited to those correctly identified in the first. The ratio of correctly identified inverted photographs to correctly identified upright photographs increased in a fairly regular manner, from about 65% at the age of 3 to about 90% at the age of 14. In the age range 3 - 5 years only two children out of 50 correctly identified all the inverted photographs, whereas 25 of the 43 children aged 10 - 14 years did so, a result which cast some doubt on the reliability of earlier observations.

A later experiment by Goldstein (1965) yielded results which appeared to be inconsistent with Brooks and Goldstein's earlier conclusions. It was found that, in learning to associate photographs of unknown faces with letters of the alphabet, the performance of second and third grade children was less dependent on orientation than

was the case for college-age subjects. However, in the former group the absence of an effect of inversion was evident mainly on the first 10 trials of the 15-trial series; by trial 15 there was as much, if not more, divergence between the upright and inverted learning curves as there was in the case of the adult subjects.

In an attempt to reconcile the apparent conflict between the findings of these two studies, Goldstein (1975) repeated Brooks and Goldstein's experiment using virtually the same procedure, but with a group of subjects whose ages ranged from 5 to 20 years. In that part of the range where the ages of the two groups coincided the agreement between the two sets of data was not very close, insofar as the 1963 study indicated that the inverted/upright recognition ratio is more or less constant between 10 and 14 years, whereas the later study showed it to be a decreasing function of age. However, the most important finding was that the ratio continues to decline after the age of 14, until at the age of 20 it is no higher than at the age of 3 or 4.

The purpose of Yin's (1969) study was to determine whether the effect of inversion on the recognition of three classes of mono-oriented object - houses, aeroplanes, and men in motion - is comparable to its effect on the recognition of human faces. In the first experiment the performance of adult subjects was examined by means of a forced-choice recognition task in which the inspection and test series were either both upright or both inverted. What Yin found was that all four classes of object were more difficult in the inverted position, the effect of inversion being greatest for faces, less so for houses and men in motion, and not significant for aeroplanes. In fact, in the upright position faces were the easiest object to recognize, but when inverted they were

the most difficult. Moreover, when the individual scores were examined it was found that high scores on the upright task were associated with high scores on the inverted task, except in the case of faces where the converse was true.

In Yin's second experiment a forced-choice task was employed as before, but the orientation of the inspection series was different from that of the test series (i.e., either upright inspection and inverted test, or vice versa). This modification in procedure introduced an extra element of difficulty, since the phenomenal appearance of objects changed in going from the inspection to the test series, and subjects' performance was generally degraded by comparison with the previous task. For all four classes of object, the mean score on the upright-inverted task was lower than that on the upright-upright task by about the same amount that the score on the inverted-upright task fell short of that on the inverted-inverted task. However, for faces, the upright-inverted task was disproportionately more difficult than the upright-upright.

Yin suggested two possible explanations of the atypical effects which he obtained on the face recognition tasks. In the first place, there could be a special factor associated with the recognition of faces which results in the effect of inversion being more pronounced than in the case of other classes of object. Alternatively, the different degrees of difficulty presented by faces and other objects, when inverted, might simply be a reflection of their relative difficulty when presented upright. In other words, the easier a particular class of objects is when presented upright, the more it is affected by inversion. In order to determine which of

Fig. 4.4. Face recognition experiment: A pair of faces as presented in the test series, showing the form of mask employed.



these two interpretations was more plausible, Yin carried out a third experiment to compare memory for faces with memory for a class of object (figures in period costume) which is as easy to remember when presented upright, but which at the same time is mono-oriented, complex, familiar, and not easily verbalized. The results supported the first interpretation above.

Procedure

A method similar to that employed by Brooks and Goldstein (1963) and Goldstein (1975), in which subjects were presented with photographs of familiar peers, would have been impractical in this study, since the children taking part were drawn from at least twenty different classes. In the circumstances it was more convenient to assess face recognition performance by means of a forced-choice memory task, as Yin (1969) did.

The materials consisted of 96 black and white photographs of 7- to 11-year-old boys and girls who were all pupils at the same school (not one attended by subjects taking part in the experiment). Photographs of children who had prominent distinguishing features, such as spectacles, were excluded. In addition, the faces were masked, as shown in Fig. 4.4, so as to obscure the external profile of the hair, which frequently possessed easily recognizable characteristics. Positive prints of the faces were re-photographed with a white paper mask in place and reproduced as 35 mm transparencies. When projected on a screen from a distance of 9½ feet the faces were approximately full-scale.

There were two tasks. In the first the inspection and test series were both upright, while in the second the inspection series was upright and the test series was inverted. In both tasks the inspection series

consisted of 24 single faces (a different set in each case) and the test series consisted of 24 pairs of faces. One member of each test pair also occurred in the inspection series at a corresponding position in the order of presentation; the second face did not occur in the inspection series. The two faces in each pair were arranged side by side, the position (left or right) of the correct one being varied at random from one pair to the next. The subject was seated about four feet in front of the screen, and the inspection faces were presented one at a time for three seconds each. Immediately after this presentation the subject viewed the test series at his own pace. He had previously been supplied with a score sheet and was instructed to indicate the correct face by placing a tick in either the left-hand or right-hand column of a 2 x 24 block of numbered boxes. Half the subjects performed the upright-inverted task after the upright-upright one, and half performed them in the opposite order. In order to minimize interference between the first and second set of faces children read or worked on a puzzle between tasks. The Verbal control group did not take part in this experiment, the subjects being restricted to the retarded readers and the Performance control group.

Results

Table 4.6 shows the mean number of faces recognized in the upright (U) and inverted (I) test series (max. score = 24) by the retarded readers and normal readers (Performance control) of Groups I, II, and III, together with the corresponding mean I/U recognition ratios. Most groups obtained a mean score on the inverted series which was quite close to the value (12) that would be expected had responses been made on a random

Table 4.6 Face recognition under inversion in retarded readers and normal readers (Performance control) of Group I (N = 11), Group II (N = 9), and Group III (N = 10).

	Group I		Group II		Group III	
	RR	NR(PC)	RR	NR(PC)	RR	NR(PC)
Mean CA	9:4	9:4	9:6	9:7	11:5	11:9
Mean no. of correct faces:						
U Series	19.5	18.9	18.9	18.6	18.6	18.5
I Series	12.9	14.8	14.1	14.4	14.8	16.9
Mean I/U Ratio (%)	67.0	78.9	75.7	78.7	81.1	92.9

Table 4.7 The recognition of words and faces under spatial transformation: A comparison of retarded readers who made orientation errors on the Schonell Spelling Test (Subgroup A) and those who did not (Subgroup B).

	Subgroup A		Subgroup B		t test (1-tail)	
	Mean	SD	Mean	SD	Value	Sig. Level
CA	9:10	-	10:0	-	-	-
Word Recognition						
<u>T-Ratios</u> (%)						
Familiar Words						
U/I	35.8	11.2	31.2	13.3	0.95	NS
U/R	31.3	12.6	34.0	21.8	-0.38	NS
Unfamiliar Words						
U/I	71.3	24.8	64.6	18.3	0.78	NS
U/R	73.8	20.9	64.3	24.3	1.01	NS
<u>N-Ratios</u>						
Familiar Words						
I/U	64.9	9.6	74.6	16.7	-1.78	p<0.05
R/U	61.7	15.6	74.2	27.1	-1.41	NS
Unfamiliar Words						
I/U	73.0	27.2	76.1	51.3	-0.17	NS
R/U	89.6	33.4	72.9	25.7	1.38	NS
Face Recognition						
I/U N-Ratio	76.8	19.0	70.7	12.2	1.01	NS

basis. Accordingly, before proceeding to a comparison of recognition ratios it was necessary to verify whether the inverted series scores were significantly above chance level. A t test (1-tail) showed that all age/reading ability subgroups, with the exception of Group I retarded readers, obtained a mean score which was significantly greater than 12 ($p < 0.025$). Although it is not valid, therefore, to analyze Group I's results in terms of I/U ratios, the absolute scores tend to indicate that it was the normal readers who had greater success on the inverted series, and in fact their mean score (14.8) was significantly higher than that of the retarded readers (t test with paired observations (2-tail): $t = 2.38$, $df = 10$, $p < 0.05$). An analysis of I/U ratios for Groups II and III showed that in neither case was there a significant difference between the retarded and normal readers (t test with paired observations (2-tail): $t = -0.40$, $df = 8$ (Group II); $t = -1.64$, $df = 9$ (Group III)).

Although all but one of the age/reading ability subgroups obtained a mean score on the inverted series which exceeded 50% (chance level) by an acceptable margin, a shorter series (of 18 - 20 items, say) would have provided a task which was better matched to children's capacities and helped to raise the overall level of performance to a more satisfactory level. Using a test series which also consisted of 24 items, Yin found that adult subjects were able to recognize, on average, over 23 upright faces and over 20 inverted faces. Boys aged 9 - 11 years would therefore appear to have poorer memory for faces than adults. However, it is believed that the difference is largely due to the fact that the faces were masked in this experiment, whereas in Yin's they were not. For if masking is of no consequence and children's memory for faces actually improves after the age of 8 or 9 years, it should be possible to detect

the change over a period of 2½ years (the age range of the complete sample), but no trend of this kind was evident in the data. Even if changes do occur in this period, as some recent work suggests, any improvement after the age of 11 or 12 would appear to be minimal. Findings which point to this conclusion have been reported by Feinman and Entwistle (1976). In their main study, children between the ages of 6 and 11 viewed a series of 20 photographs of children's faces (unmasked) and then attempted to identify the same faces in a test series of 40. It was found that face recognition ability increases by about 15% between the ages of 6 and 8, and by a further 6% between 8 and 12. Supplementary data obtained in a pilot study showed that the performance of the 11-year-olds was essentially no different from that of college-age adults. Thus, the 20% difference in performance between Yin's adult subjects and the Cambridgeshire 9- to 11-year-olds cannot be explained by the age difference alone and suggests that masking has a substantial effect on ease of recognition.

4.4 Form recognition under spatial transformation in retarded readers who exhibit orientation confusion and those who do not.

The results of the last two experiments suggest that the effect of spatial transformation on children's recognition of text and faces is independent of their level of reading ability. However, the prediction that retarded readers' powers of recognition would be invariant with respect to figure orientation is thought to apply only to those who show evidence of orientation confusion, and it is therefore necessary to examine this group's results in more detail. To this end the 13 retarded

readers who made one or more orientation errors on the Schonell Test (Subgroup A) were compared with the remaining 15 (Subgroup B) who made no such errors. In general, Subgroups A and B were similarly affected by the disorientation of both words and faces (Table 4.7), the only exception occurring in the case of inversion of familiar words, where Subgroup B obtained a higher mean N-ratio than Subgroup A.

4.5 Discussion

The effect of inversion and reversal on children's word recognition performance was examined in relation to age, level of reading ability and word familiarity, with the primary object of determining whether retarded readers have greater facility with disoriented text than do normal readers. On the face of it, the results of the first analysis, in which T-ratios were used as an index of reading difficulty under spatial transformation, confirmed what had been found in earlier studies by Critchley and Deich. However, the significance of the finding was considerably diminished by the discovery that it could be explained by the disproportionate difficulty experienced by retarded readers in reading upright lists of unfamiliar words, rather than the relative ease of inverted or reversed lists. On analyzing N-ratios, further doubt was cast on the validity of the initial interpretation when it was found that reading level had an effect which was just the opposite of that indicated by the T-ratio analysis. (The normal readers' mean N-ratio was closer to 100% than that of the retarded readers, a result which conflicted not only with the T-ratio analysis but also with Clay's findings. However, unless it is known that T-ratios are invariant across all conditions, an unequivocal interpretation cannot be put on the relation between reading level and N-ratios,

and it is therefore impossible to determine whether the failure to confirm Clay's findings reflects a genuine difference between subjects' word recognition skills, or merely a difference in experimental procedure. By the same token, although Deich's results seemingly point to the same conclusion as Clay's, one cannot be certain about the validity of this comparison, because there is no evidence that N-ratios were invariant in the former experiment and that T-ratios were invariant in the latter.)

It was shown that the inverse relationship obtaining between N-ratios and T-ratios arose as a result of the following two characteristics of the word recognition process: (1) the number (n) of words read correctly was, in general, an inverse function of the time (t) taken to read the list, and (2) the magnitude of the T-ratio was a function of the absolute value of t , insofar as high T-ratios were the quotients of relatively high values of t , and low T-ratios were the quotients of relatively low values of t . As was pointed out above, it is not permissible to regard T-ratios as an unequivocal index of reading difficulty under spatial transformation unless N-ratios are constant across all conditions, and a similar consideration applies if N-ratios are to be used as the index. Fortunately, it was possible to carry out an analysis in which both the foregoing conditions were simultaneously satisfied. Thus, comparing the retarded readers' performance on familiar lists with the normal readers' performance on unfamiliar lists, there was close agreement, not only in terms of N- and T-ratios, but also in respect of the mean values of n and t , a reflection of the fact that, in all three orientations, the unfamiliar list was, orthographically, about as familiar to the normal readers as the familiar list was to the retarded readers. These findings were not peculiar to

text: inversion of faces had much the same effect on retarded readers' recognition performance as it did on normal readers'.

Comparing the retarded readers who made orientation errors (Subgroup A) with those who did not (Subgroup B), the former found it no easier to recognize text or faces that were presented in novel orientations. Thus, no evidence has been found to support the hypothesis that individuals who show a tendency to produce orientation errors experience little or no change in the phenomenal form of a mono-oriented figure under spatial transformation.

Chapter 5

5.1 Introduction

As part of the theory advanced in Chapter 1 it was proposed that an imaginal spatial framework might subserve two specific aspects of language acquisition, namely, the differentiation of the members of an antonymous pair of words, and the acquisition of sequences. In order to demonstrate that retarded readers in whom spatial concepts are poorly developed also present deficits in these two spheres of language it is necessary to show that in other respects their linguistic development is no different from that of either normal readers or retarded readers whose spatial abilities are well developed. It will be recalled that the Verbal control groups were formed by matching subjects on the basis of the sum of WISC Vocabulary and Similarities scores, thereby ensuring that the two groups were equal in terms of their ability to define and categorize words. Nevertheless, it was thought desirable to ascertain whether they were as well-matched on other levels of language. If retarded readers are found to be delayed, relative to normal readers, in the acquisition of antonyms and sequences, but equally mature in terms of a range of other linguistic measures, then it would tend to confirm that the former difficulties are not part of a general impoverishment of oral language - a state of affairs which might be expected to result from reduced contact with the printed word.

With a view to establishing a broader picture of children's language development, and one which would enable the significance of specific deficits to be evaluated with more confidence, it was decided to investigate some aspects of syntactic development. The first part of this

Chapter describes the two methods that were employed. The next two sections present the findings on children's understanding of certain adjective-antonym pairs, and their knowledge of a number of common series. On the basis of the latter measure, two further Subgroups of retarded readers are identified, one (C) consisting of subjects with poor memory for sequences and the other (D) consisting of those with relatively good retention. These Subgroups are then compared with each other and with their controls in respect of intellectual performance, syntactic ability, reading and spelling attainment and level of spatial thought. Finally, the question of whether there is a relationship between poor memory for sequences and the tendency to make orientation errors is examined by comparing the composition of Subgroups C and D with that of Subgroups A (orientation errors present) and B (orientation errors absent).

5.2 Syntactic development in retarded and normal readers: A review of previous studies.

Most studies of the relationship between syntactic acquisition and reading ability have concluded that retarded readers are less advanced than normal readers. The choice of syntactic measures to demonstrate that the oral language development of the sample under study is independent of reading ability would therefore appear to be misguided. However, as Fry, Johnson and Muehl (1970) have pointed out, several of the earlier studies (Barnes, 1962; Martin, 1955; Shire, 1945; Winter, 1957) which demonstrated an association between these two factors, failed to control or allow for the effects of other factors such as intelligence, social class, and sex. In those that did so (Cordes, 1965; Lovell, Shapton, and Warren, 1964; Raulin, 1962) some of the language measures (e.g., the Watt's English Language Scale used by Lovell et al.) indicated that retarded readers are as advanced as normal readers.

In an attempt to remedy the shortcomings of earlier studies, Fry et al. carried out an analysis of oral language production in 36 below-average readers (24 boys and 12 girls), aged 7:1 to 8:0, and 21 average, or above, readers who were matched (in terms of mean scores) for age, sex ratio, intelligence (Lorge-Thorndike), and social class. A sample of oral language was elicited by asking the subject to tell a story about each of a series of twenty pictures. Two analyses were carried out on the subjects' protocols, the first involving traditional measures such as the total number of words, total number of different words, and type-token ratio (McCarthy, 1930; Templin, 1957; Winitz, 1959), together with more recently developed procedures based on the communication unit (CU) (Kean, 1965; Loban, 1963; Strickland, 1962), which provide a detailed picture of the child's syntax, including types and frequencies of patterns (Strickland's Level I analysis), satellite groups (Strickland's Level II analysis), and an index of subordination. The analysis yielded a total of 59 measures, and on 16 of these the above-average readers demonstrated a significantly higher level of proficiency than the below-average readers. Not only did the better readers use more words in talking about the pictures, they also used more different words, confirming the previous findings of Martin (1955), Raulin (1962), and Shire (1945). The analysis of syntactic structure showed that the above-average readers made more frequent use of modification in the predicate position of their speech than did the poor readers, but less frequent use of it in the subject position, a pattern of behaviour which could be taken to indicate greater linguistic maturity on the part of the above-average readers. Another prominent difference was the much higher frequency of "existence" sentences in the speech of below-average readers. However, Fry et al.

consider that this sentence type would be less common in ordinary usage and that its frequent occurrence in the test situation probably reflects the difficulty encountered by poor readers in organizing and structuring a story.

The second analysis carried out by Fry et al. was based on a transformational model and was concerned with identifying the types of transformational rules (T-rules), and their frequencies, occurring in the first 50 CUs produced by each subject. Altogether, 37 different T-rules were used, 36 of which were found in the speech of at least one member of both reading ability groups. Only nineteen distributions of T-rule usage were amenable to statistical analysis, and in five cases the median values of the above-average readers' scores were significantly different from those of the below-average readers. The latter group used more contractions, violated subject-verb agreement in number more often, used more nominal compounds, used more "existence" sentences, and produced a smaller number of transformations in 50 CUs than the former.

Thus the oral language deficiencies of below-average readers appear to be confined to a relatively small set of measures. It is also clear from the results of their first analysis that Fry et al.'s method of controlling for IQ resulted in two groups which differed in vocabulary level. Now, the magnitudes of intercorrelations between the vocabulary measure (total different words given in response to 10 pictures) and the other measures on which there were significant reading group differences exceeded 0.32 in every case but one. So, if vocabulary were to be controlled, as in the present study, one would expect the inter-group differences on these other measures to be considerably attenuated.

Vogel (1975), who was apparently unaware of Fry et al.'s work, set out to demonstrate that dyslexic children exhibit a specific deficiency in syntactic ability. Twenty boys aged 7:4 to 8:5 whose scores on both the Comprehension and the Speed and Accuracy subtests of the Gates-MacGinitie Reading Test were 1 SD or more below the mean, were matched for age (+/- 3 months) with 20 normal readers whose scores on the same tests were at, or above, the 50th percentile. Though subjects were matched on only one factor - age, they were required to satisfy certain minimum levels of performance in respect of receptive vocabulary (Peabody Picture Vocabulary Test (PPVT) standardized score greater than 85), intellectual ability (Caldwell's Preschool Inventory IQ not more than 1 SD below the mean), and social class (father's occupational rating above lower fifth of the scale). When the two groups were subsequently compared it was found that there were no significant differences either in terms of PPVT score or social class distribution (a comparison of the groups' intelligence levels could not be made because in seven cases the assessment was based on tests other than the Preschool Inventory). Syntactic development was assessed by means of a series of eight tests. The first four were concerned with aspects of receptive language: Recognition of Melody Pattern (which assesses the child's ability to distinguish between intonation patterns associated with declarative and interrogative sentences); Recognition of Grammaticality (modelled after the Metropolitan Achievement Tests of Language Usage); Comprehension of Syntax (using the Northwestern Syntax Screening Test); and Sentence Repetition. The remaining four tests were designed to assess aspects of syntax and morphology in expressive language: the Berry-Talbot Test (which assesses the child's knowledge of morphological rules); the Gramatic Closure

Subtest of the Illinois Test of Psycholinguistic Abilities (also a test of morphological knowledge); an Oral Cloze test (of which there were two versions - one involving a passage of low transformational complexity and the other a passage of high complexity); and, lastly, a sample of the child's free speech was analyzed using the Developmental Sentence Scoring procedure (Lee and Canter, 1971). The dyslexics' performance was found to be significantly inferior to that of the normal readers on all measures except the Recognition of Grammaticality test and the Northwestern Syntax Screening test. Vogel used a number of supplementary tests, including a test of auditory memory, and further analysis showed that this factor was significantly correlated with performance on two of the syntactic measures - Sentence Repetition and the Oral Cloze test. An analysis of covariance was therefore used to adjust for the linear effects of auditory memory on the dependent variables, with the result that the difference between the groups on the Oral Cloze test reduced to a non-significant level. Vogel considers that the results bear out her hypothesis, the fact that three of the measures failed to differentiate between the two groups being glossed over without any attempt to analyse what aspects of syntax presented particular difficulties to the dyslexics. Quite apart from this shortcoming, Vogel's method is not the most satisfactory way of determining children's syntactic strengths and weaknesses, because a heterogeneous group of tests, based on different language models, is unlikely to provide a complete and systematic picture of syntactic development.

Although the methods used by Fry et al. are to be preferred, at least until it has been reliably established how retarded readers' syntactic

development differs from that of normal readers, it would have been impracticable in this study to base the syntactic analysis on samples of children's free speech, and it was therefore necessary to select specific areas of language development for investigation. The choice of appropriate measures was guided by the findings of some earlier studies which are described in the following two sections.

5.3 Children's implicit knowledge of parts-of-speech.

Introduction

It has been shown by Ervin (1957) and Brown and Berko (1960) that children's word associations undergo systematic developmental changes. Whereas younger children's responses in a word association task seem to be governed by such principles as spatial or temporal contiguity, word-to-word transition probabilities, and similarity or contrast of referents, the responses of the older child and the adult are to a much greater degree determined by the part-of-speech of the stimulus word, though the influence of at least some of the above principles can still be detected. Brown and Berko describe responses which belong to the same word class as the stimulus as homogeneous-by-part-of-speech (abbreviated Hmg.) and those which belong to a different word class as heterogeneous-by-part-of-speech (Htg.). They proposed that the proportion of Hmg. responses to a given word class could provide an index of proficiency in making correct grammatical use of newly-encountered words in the same class. To test this hypothesis children were introduced to a series of 12 "new" words (pronounceable nonsense syllables) belonging to one of six parts-of-speech: count nouns, mass nouns, adjectives, transitive verbs, intransitive verbs,

and adverbs. Each nonsense word was embedded in a sentence frame in such a way that the part of speech to which it belonged was apparent from the position it occupied. For example, where the nonsense word wug was to be identified as a count noun it was embedded in the following question: "Do you know what a wug is?" Two sentences containing the word were read to the child with the object of eliciting a response which demonstrated that he had registered the class to which it belonged. To focus the child's attention and help him formulate a response, a picture was presented with each word, but it offered no clues as to the "meaning" of the new word. For example, the sentence above containing the word wug was accompanied by a picture of a girl and the experimenter would say: "Do you know what a wug is? This is a picture of a girl thinking about a wug. Can you make up what that might mean?" The children also performed a free association task involving six words from each of the six word classes featured in the usage test. Mean Hmg. scores on the association and usage tests were computed for each part-of-speech and for each of the four age groups (1st, 2nd, and 3rd grade children, and adults). The means obtained on the former test were then correlated with the means on the latter, yielding a highly significant ($p < 0.001$) value of rho (0.84). When the variation due to age was eliminated by collapsing mean scores across age levels, within parts-of-speech, the intercorrelation between association and usage grand means was still significant (rho = 0.94, $p = 0.01$), bearing out the claim that homogeneity of associative responses provides a valid index of the child's ability to infer the class of a word from its syntactic context, and make correct grammatical use of it in a new context.

Brown and Berko's word association test was included in a battery of tests used by Doehring (1968) to compare the verbal and non-verbal

abilities of retarded and normal readers. The two groups were matched for age (10 to 14 years) and Wechsler-Bellevue Performance IQ, but not for Verbal IQ. Failure to control for the latter factor resulted in the normal readers being significantly superior to the retarded readers on a number of verbal measures, including the Vocabulary and Similarities subtests of the Wechsler-Bellevue and the Sentence Repetition and Oral Comprehension subtests of the Minnesota Test for Differential Diagnosis of Aphasia, but not on the Brown and Berko word association task, leading Doehring to conclude that "the retarded readers were not deficient in basic habits of grammatical usage." (p. 50) In view of these findings, it was thought that the word association task would prove equally capable of demonstrating the independence of reading ability and syntactic development in the present sample, particularly as the retarded and normal readers were matched for short form WISC Verbal score.

Procedure

The test was a shortened version of the one developed by Brown and Berko and consisted of three words from each of the six classes, as shown below. The numbers in parentheses following each word indicate its position in the order of presentation. Two practice words, salt (MN) and boy (CN), preceded the test proper.

Count Nouns (CN): foot (1), table (11), house (15)
 Mass Nouns (MN): sand (3), water (7), milk (16)
 Adjectives (Adj): dark (6), soft (14), cold (17)
 Transitive Verbs (TV): to find (4), to bring (9), to send (18)
 Intransitive Verbs (IV): to laugh (5), to come (10), to live (13)
 Adverbs (Adv): quickly (2), slowly (8), sadly (12)

The test was explained to the child in the following way:

"I am going to say a word and I want you to listen to my word and then say another word, which is different from my word. Any word is alright as long as it is the first word that comes into your head when you hear my word. Are you ready?"

If the child did not respond within about five seconds, the next word was presented and any which failed to produce an association were presented again at the end of the series. Children rarely produced Htg. responses to the practice words, but those who did so were encouraged to think of other associations until one in the correct class was produced, though no hints were given as to what constituted a correct response.

Results

There were eight instances, in the whole sample, where the child supplied a word that belonged to the correct class but which can also assume membership of a different class. All such responses were counted as homogeneous, as were responses which were in the form of a participle, provided that the corresponding verb belonged to the correct class. The mean numbers of Htg. responses made by the retarded and normal readers of Groups I, II, and III, in each of the six word classes, together with the grand means over all classes, are shown in Table 5.1. The t test with paired observations was used to compare the retarded readers and normal readers on the mean numbers of Htg. responses (all classes), but no significant differences were found for Group I ($t = -1.05$, $df = 10$), Group II ($t = -0.09$, $df = 8$), or Group III ($t = 0.96$, $df = 9$). In Table 5.1 the parts-of-speech are listed in the order which corresponds to that of the mean scores obtained in each class by Brown and Berko's subjects. It may be seen from the All Groups columns that the results of the Cambridge subjects conform to the same pattern, except that the positions of the CN and Adj classes are reversed in the case of the retarded readers, while the IV and TV classes are reversed in the case of the normal readers.

Table 5.1 Word association test: Mean number of Hmg. responses, in each word class, made by retarded readers and normal readers (Verbal control) of Groups I, II, and III.

	Group I		Group II		Group III		All Groups		Brown and Berko's adult Ss (N = 20)
	RR	NR (VC)	RR	NR (VC)	RR	NR (VC)	RR	NR (VC)	
Mean CA	9:5	9:4	10:0	9:11	11:6	11:8	10:4	10:4	-
Mean no. of Hmg. responses									
CN	2.82	2.73	2.67	2.67	2.90	2.30	2.80	2.57	2.55
Adj	3.00	2.45	2.78	2.33	2.80	1.90	2.87	2.23	2.50
IV	2.18	2.36	1.78	1.56	1.90	1.90	1.97	1.97	2.40
TV	1.18	1.73	2.44	2.33	1.80	2.20	1.77	2.07	2.23
ADV	1.73	1.91	1.56	1.78	1.60	1.40	1.63	1.70	2.48
MN	0.64	1.36	0.44	0.78	1.30	0.80	0.80	1.00	1.18
Total	11.55	12.55	11.33	11.44	12.30	10.50	11.73	11.53	13.34

Table 5.2 The five structures used to assess children's syntactic comprehension (after Chomsky, 1969).

Structure	Implicit phrase to be identified	Incorrect candidate	Correct candidate
1) EASY TO SEE, as in the sentence: The doll is easy to see.	subject of <u>see</u>	doll	somebody else
2) PROMISE, as in the sentence: Coco promises Donald to lie down.	subject of <u>lie down</u>	Donald	Coco
3) ASK, as in the sentence: The girl asks the boy what to paint.	subject of <u>paint</u>	boy	girl
4) AND, as in the sentence: Mother scolded Gill for answering the phone, and I would have done the same.	referent of <u>done the same</u>	answered the phone	scolded
5) ALTHOUGH, as in the sentence: Mother scolded Gill for answering the phone, although I would have done the same.	referent of <u>done the same</u>	scolded	answered the phone

It will be recalled from Chapter 3 that the retarded readers of Subgroup B (orientation errors absent) had better-developed vocabularies than those of Subgroup A (orientation errors present), and it might be supposed, therefore, that they would also differ in their knowledge of word classes. However, further analysis showed that the mean number of Hmg. responses (10.9) made by Subgroup A (N = 12, Mean CA = 10:2) was not significantly different from the mean score (11.5) obtained by Subgroup B (N = 12, Mean CA = 10:3), ($t = -0.57$, $df = 22$). Further discussion of these results will be left until the concluding section of this Chapter.

5.4 Comprehension of sentence structures which are exceptions to the Minimum Distance Principle

C. Chomsky (1969) has identified a series of five syntactic structures which, it is claimed, are acquired in an invariant order between the ages of about six and ten years. What all these sentences (see Table 5.2) have in common is a surface structure in which a noun phrase or verb phrase from the underlying deep structure is deleted, so that it is necessary for the child to identify either the implicit subject of a complement clause or the implicit referent of a verb phrase. Usually the identity of the deleted noun or verb phrase is determined by a rule known as the Minimum Distance Principle (Rosenbaum, 1967) which states that the phrase to be recovered is the one immediately preceding the truncated clause. However, the five syntactic structures selected by Chomsky are all exceptions to this rule in that the subject or verb referent missing from the clause is not the nearest phrase but one earlier in the sentence. Although Chomsky found that the order of

acquisition of these exceptional structures was the same for over 95% of her subjects (36 children drawn from kindergarten up to fourth grade, and representative in terms of age and reading level), there was a great deal of variation in individual rates of development, some children reaching Stage 5 by age 7:6, while others were still at Stage 2 at 9:5.

In the same study Chomsky attempted to relate the child's level of syntactic development to his reading habits, and to this end information on five measures relating to the number and quality of books read was obtained through separate interviews with the child and one of his parents. Significant correlations were found between linguistic stage and all five measures of reading experience. Chomsky recognized that these relationships might reflect the effect of age, IQ, and social class, all of which were significantly correlated with linguistic stage as well, but the question of whether an effect of reading experience remains when the influence of these other variables has been allowed for was not dealt with in a very satisfactory manner. For reasons which are not entirely clear, the usual method of providing an answer to this type of question, namely partial correlation, was not employed. Instead, in an attempt to demonstrate a relationship between reading experience and linguistic development when age and IQ are controlled, Chomsky carried out a series of three "mini-comparisons", the numbers of children involved being too small to permit statistical tests to be applied. Three children were compared at each of three different age levels (5:9 to 6:1; 7:10 to 8:6; 9:4 to 10:0). Within each age range the three subjects varied in their level of linguistic development, but were matched for IQ. Inspection of the data revealed an association between several of the reading experience measures and linguistic stage of

development. Although not all of these measures differentiated between children at every age level, there were three which did so: the number of books named by the child in the course of his interview, the average number of books taken out on regular visits to the public library, and the number of books which the mother recalled from her own childhood and had also enjoyed reading to the child. In the light of these findings, it is somewhat surprising to note that in the mini-comparisons involving the two upper age ranges there was no clear-cut relationship between linguistic stage of development and either their reading vocabulary or their reading comprehension scores. (The corresponding data for the lower age range were not reported.) However, there is some doubt as to whether Chomsky's data provide a true picture of the situation, in view of a recent study by Goldman (1976) which showed that reading skill (as measured by the Metropolitan Reading Test, Elementary Form) was a better predictor of 7- to 11-year-old children's comprehension of sentences containing the structure promise than either age or IQ.

Several other developments relating to syntax occur after the age of 7 - 8 years, apart from those identified by Chomsky, but at the time the study was being designed only a limited number of structure-specific test procedures had been developed for use in this age range. Moreover, Goldman's study had not yet been published, and as far as could be determined from Chomsky's study the acquisition of exceptions to the Minimum Distance Principle was independent of reading ability, though not of amount and kind of reading experience. It was hoped that the performance of the Cambridge sample on the same five structures would allow similar conclusions to be reached, though it was realized that Chomsky's analysis, involving a comparison of individual test scores, could not be

relied on to reveal the true nature of the association.

Procedure

The test materials and procedures were virtually identical to those used by Chomsky (1969, 1972) and the following account does no more than outline them, though care is taken to note any departures from the original form of the tests. The reader is referred to Chomsky (1969, 1972) for further details.

(A) The structure easy to see in the sentence: "Is the doll easy to see or hard to see?". The child was shown a doll, which had eyes that open and close, lying face upwards on the table. He was asked: "Is the doll easy to see or hard to see?" Irrespective of his response, he was then asked: "Why?" Depending on whether his answer to the first question had been "easy" or "hard" he was next asked to make the doll either "hard to see" or "easy to see". (Children who have not acquired this structure answer "Hard" to the first question and "Because her eyes are closed" to the second.) A score of 1 point was awarded for each question responded to correctly and without hesitation. If the child failed to respond initially, or produced an ambiguous answer, but, after hearing the question repeated one or more times, responded correctly, a score of ½ point was given. Children were often nonplussed by this task, probably on account of its extreme simplicity, and it frequently happened that they were unable to formulate an answer to the second question, even when they responded correctly to the first and last. The criterion for success was therefore made less exacting than it otherwise might have been, a score of at least ½ point on the first and last questions being judged sufficient to demonstrate that the child had acquired this structure.

(B) The construction promise, as in the sentence: "Coco promises Donald to stand on the book."

First of all, to ascertain whether the child knew the meaning of the word promise, the following three questions were put to him:

- (a) "Can you tell me what you would say to your friend if you promise him that you'll call at his house on Saturday?"
- (b) "What do you mean when you make somebody a promise?"
- (c) "What's special about a promise?"

(Question (c) was frequently omitted if a full answer was given to Question (b)). The method used to assess the child's understanding of promise required him to enact a series of sentences containing the word, but before these were presented he attempted a series of three practice sentences containing simpler constructions in order to familiarize him with this type of task. Accordingly, the child was provided with two toy figures, Coco the Clown and Donald Duck, and asked to manipulate them so as to illustrate the actions described in the following sentences:

- (d) "Coco wants to do a somersault - make him do it."
- (e) "Coco wants Donald to do a somersault - have him do it."
- (f) "Donald decides to stand on the book - make him do it."

Then followed the sentences containing promise:

- (g) "Donald promises Coco to hop up and down -- make him hop."
- (h) "Coco promises Donald to stand on the book -- make him do it."
- (i) "Coco promises Donald to stand on his head -- make him do it."
- (j) "Donald promises Coco to run in a circle -- make him do it."
- (k) "Coco promises Donald to lie down -- make him do it."

Correct responses, made without hesitation, received a score of 1 point. If the child picked up the wrong figure, but then corrected himself of his own accord, he was awarded a score of ½ point. Following Chomsky (1969), the criterion for successful acquisition of this construction was a minimum of four correct responses to questions (g) to (k) (or a combination of full points and ½ points exceeding four in total).

(C) The construction ask, as in the sentence: "The girl asks the boy what to paint."

Chomsky (1969) devised two techniques to assess the child's understanding of the word ask, but only one of them - the picture identification method - was used in this study. What the child was required to do was indicate which interpretation of a sentence containing ask was correct by making a choice between two pictures. As a further check on his understanding of this structure he constructed a sentence which expressed what one person in the picture was saying to the other. Three sets of pictures were used (one more than in Chomsky's (1972) study): they are shown in Fig. 5.1, together with the accompanying questions. The criterion of successful acquisition was an error-free performance on both parts of all three problems. (Chomsky's criterion, based on two sets of pictures, was similar, but in addition demanded correct performance on 4/5 of the instructions given in the conversation test.)

(D) Constructions following And and Although.

The implicit referent of the verb in the second clause of the following sentences is determined by the conjunction which precedes it:

- (e) "Mother scolded Gill for answering the phone, and I would have done the same."
- (f) "Mother scolded Gill for answering the phone, although I would have done the same."

Before presenting the above sentences to the child for his interpretation, it was first established that he knew the meaning of the word although by asking him to complete the following two sentences:

- (a) "Although my favourite TV program was on, I"
- (b) "I wore a heavy jacket although"

The child next solved the following two comprehension problems to confirm that he could correctly identify the implicit subject of a prepositional phrase modifying the main verb:

- (c) "Mother scolded Gill for answering the phone. Who answered the phone?"
- (d) "The cowboy scolded the horse for running away. Who ran away?"

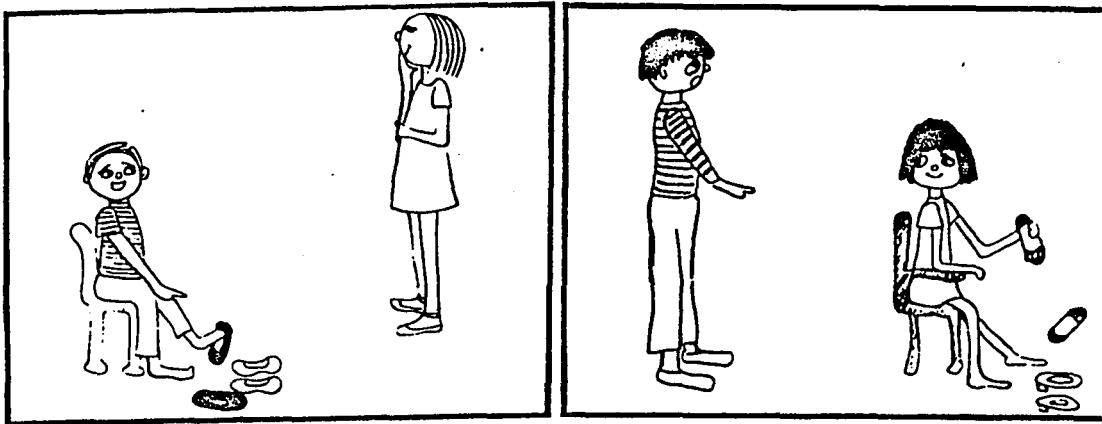


Fig. 5.1(a). Test Pictures: Correct Interpretation (left), and Incorrect Interpretation (right). Test sentence: The boy asks the girl what shoes to wear. Subject is shown both pictures simultaneously and asked: 1. Which picture shows the boy asking the girl what shoes to wear? 2. (after selection) What is he saying to her?

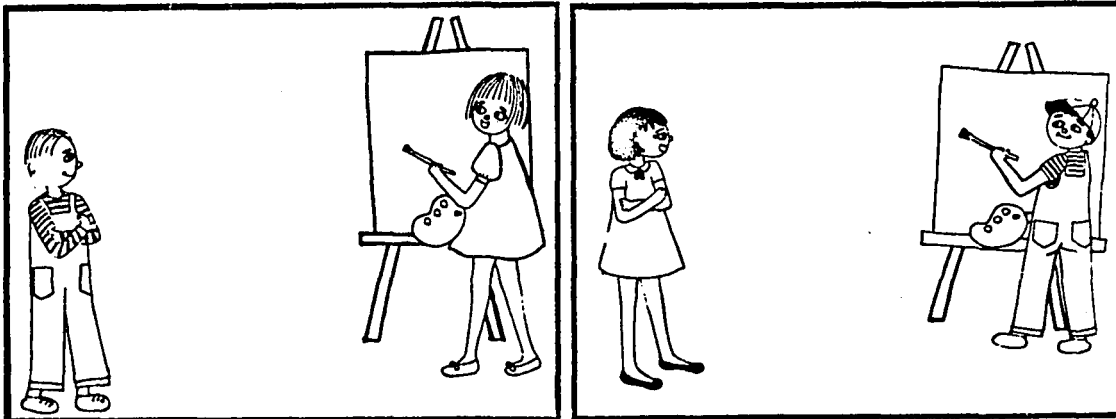


Fig. 5.1(b). Test Pictures: Correct Interpretation (left) and Incorrect Interpretation (right). Test sentence: The girl asks the boy what to paint. Subject is shown both pictures simultaneously and asked: 1. Which picture shows the girl asking the boy what to paint? 2. (after selection) What is she saying to him?

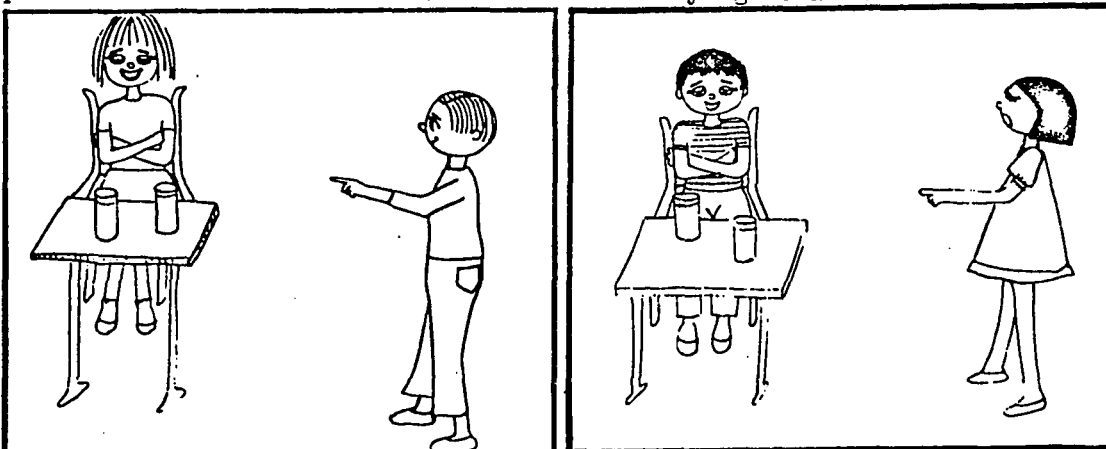


Fig. 5.1(c). Test Pictures: Correct Interpretation (left), and Incorrect Interpretation (right). Test sentence: The girl asks the boy which juice to drink. Subject is shown both pictures simultaneously and asked: 1. Which picture shows the girl asking the boy which juice to drink? 2. (after selection) What is she saying to him?

(after C. Chomsky (1969))

Sentences (e) and (f), above, were then read to the child, each one being followed by the question: "What does this sentence say I would have done?" There were two further examples of these constructions, namely:

- (g) "The cowboy scolded the horse for running away, and I would have done the same."
- (h) "The cowboy scolded the horse for running away, although I would have done the same."

If the child produced correct responses to problems (e) and (f) he was considered to have acquired the and construction, and if, in addition, he responded correctly to (g) and (h) he was assumed to understand the although construction.

Results

Chomsky found that the great majority of children acquire the above constructions in an invariant order, a feature of their performance which made it possible to define a five-stage developmental scale. At Stage 1 are children who fail all five constructions. Children at Stage 2 succeed with easy to see (A) but fail the remainder; children at Stage 3 succeed with easy to see and promise (B); children at Stage 4 have acquired two further constructions, ask (C) and and (D1); and finally at Stage 5 children succeed with all five constructions (A - D2). However, judging by the results obtained for the Cambridge sample, Goldman would appear to be justified in her criticism that the developmental progression is not as well defined as Chomsky suggests. The first difficulty arose in connection with the assignment of children to Stage 4 which, assuming Stage 3 has been mastered, requires the acquisition of two further constructions, namely ask (C) and and (D1). Of the 38 children who had acquired at least the first two structures (A and B), 10 understood ask (C) but not and (D1), 13 understood and but not ask, and 15 understood both. Furthermore, 3 children had

acquired construction B (promise) before A (easy to see) and four had acquired C and/or D1 before B. Thus, there was considerable deviation from the order of acquisition posited by Chomsky, and it was therefore decided to define the child's level of performance in terms of the number of constructions which he comprehended, irrespective of whether they conformed with this order or not. Table 5.3 shows the number of constructions understood by the retarded readers and normal readers (Verbal control) of Groups I, II, and III, together with the combined figures for the complete sample. On average, the retarded readers (All Groups) had acquired exactly the same number of structures (2.9) as the normal readers, and a Wilcoxon, matched pairs, signed ranks, test applied to each age range separately as well as the complete sample showed that there were no significant differences between the two reading ability groups.

Table 5.4 shows the numbers of retarded and normal readers in the complete sample who had acquired each structure. Contrary to what Goldman found for children in a slightly lower age range (7:9 to 11:5), the great majority of retarded readers in this sample understood the construction promise. Moreover, the proportion of subjects who had acquired the other four structures did not differ appreciably from one reading ability group to the other.

Consistent with their performance on the word association test, the two Subgroups of retarded readers distinguished by the presence (A) or absence (B) of orientation errors did not differ in their comprehension of the five syntactic structures. In fact, the mean number of structures understood by Subgroup A (N = 12, Mean CA = 10:1) was 2.92, fractionally greater than the mean number (2.83) understood by Subgroup B (N = 12, Mean CA = 10:3).

Table 5.3. Comprehension of five syntactic structures: The number of constructions acquired by retarded readers and normal readers (Verbal Control) of Groups I, II, and III.

	Group I		Group II		Group III		All Groups	
	RR	NR (VC)	RR	NR (VC)	RR	NR (VC)	RR	NR (VC)
Mean CA	9:6	9:5	9:11	9:10	11:7	11:9	10:4	10:4
Number of constructions acquired								
0	0	1	0	0	0	0	0	1
1	0	0	2	1	0	1	2	2
2	3	3	3	1	1	4	7	8
3	7	3	1	3	6	1	14	7
4	0	4	3	4	2	3	5	11
5	1	0	0	0	1	1	2	1

Table 5.4. Comprehension of five syntactic structures: Numbers of retarded readers and normal readers (Verbal control) (All Groups) who had acquired each construction.

Structure	No. of Ss (All Groups) comprehending structure	
	RR	NR(VC)
A (<u>easy to see</u>)	29	27
B (<u>promise</u>)	27	24
C (<u>ask</u>)	16	15
D1 (<u>and</u>)	13	18
D2 (<u>although</u>)	3	4

5.5 Children's comprehension of adjective-antonym pairs

Introduction

Reports concerning the oral language abilities of dyslexic children occasionally make reference to the type of error in which an antonym is substituted for the correct adjective, adverb, or verb. For example, amongst the "reversals of concepts" noted by Saunders (1962) were: "hostile for hospitable, floor for ceiling, go for stop." Saunders also observed that:

"Confusion of direction often is heard from these children, east for west, up for down, under for over; and time sequences also can be reversed: first for last, now for later, seldom for often. One child said, "The day after yesterday.....I mean the day before tomorrow," when what he really meant was the day after tomorrow." (p.38).

Bender (1958) found similar difficulties in children with "developmental alexia", a condition which was said to include delayed speech and language development, clumsiness and lack of coordination, and reading retardation:

"Great difficulty arises with terms such as "now", "then", "tomorrow", and "yesterday" (also spatial concepts of "here" and "there"). These children live more in the immediate present than do non-alexia children. In the same way they cannot understand the past, present, and future tenses of verbs. They are lacking in concepts of either the immediate time about them or the immediate space about them" (p.171).

However, in Critchley's (1970) series of 125 dyslexics this type of confusion was hardly ever encountered:

"Thus inadequacies in syntax and in vocabulary may at times be discerned. For example, the child may emit what might be called reversals of concepts, saying for example, black for white, nice for nasty. In my experience this has been most exceptional. Direction is frequently muddled but it is often hard to decide whether it is a spatial or linguistic defect" (p.81).

Commenting on Saunders' observation cited above, Critchley concludes that:

"...these disorders of language and diction are inconsistent, and they are best regarded as being epiphenomena, and rare at that" (p.82).

In the field of normal language development, several investigators concerned with the acquisition of relational terms have suggested that there is a stage in the child's development when he interprets both members of an antonymous pair of adjectives as having the same meaning - generally that of the positive (unmarked) term. These studies have for the most part been concerned with semantic development in the age range 3 to 7 years and have used a variety of production and comprehension tasks, most of which involved toys or pictures to provide a context for the discourse. Presumably, similar methods could be used to assess how frequently older children confuse familiar adjectives with their antonyms, but if, as some reports suggest, the phenomenon is rare, it is doubtful whether the error rates obtained would be high enough to permit a statistical test to be carried out. An alternative approach is to assess the acquisition of less familiar adjectives which enter the child's vocabulary between the ages of 8 and 12, say. This method rests on the assumption that any tendency on the part of retarded readers to confuse the members of an antonymous pair of adjectives will be sufficiently amplified during the acquisition phase to be distinguishable from the error rate which normally obtains.

Procedure

A test of comprehension was designed using ten pairs of antonyms (see Table 5.5). Each word was embedded in two sentence frames, one of which implicitly defined the adjective, and the other which negated it by defining its opposite. For example, the following two sentence frames were used with the word feeble:

Table 5.5 The ten adjective-antonym pairs used to assess the incidence of concept reversals. (The number in brackets following each word refers to its frequency of occurrence per 4.5 million words, according to the J column of Thorndike-Lorge word count.)

(1) scarce (130)	-	abundant (79)
(2) skilful (102)	-	clumsy (80)
(3) mild (134)	-	harsh (58)
(4) feeble (126)	-	effective (44)
(5) alert (77)	-	drowsy (36)
(6) confined (55)	-	extensive (33)
(7) brisk (36)	-	sluggish (22)
(8) extravagant (26)	-	economical (11)
(9) injurious (17)	-	beneficial (11)
(10) subordinate (14)	-	dominant (12)

Table 5.6 Comprehension of ten adjective-antonym pairs: Scores obtained by retarded readers and normal readers (Verbal Control) of Groups I, II, and III.

	Group I		Group II		Group III	
	RR	NR(VC)	RR	NR(VC)	RR	NR(VC)
CA	Mean	SD	Mean	SD	Mean	SD
	9:11	0:4	9:10	0:5	10:5	0:6
	10:4	0:8	11:10	0:6	12:0	0:11
Comprehension measure:						
(1) No. of adjs. correct	8.0	3.6	8.1	2.9	9.2	3.0
	(t = -0.08, NS)		(t = -0.44, NS)		(t = -0.80, NS)	
(2) No. of ant. pairs correct	2.3	1.7	2.5	1.8	2.7	1.8
	(t = -0.30, NS)		(t = -0.61, NS)		(t = 0.32, NS)	

- (1) The newly-born foal had such feeble legs he found it difficult to stay on his feet.
- (2) The new crane was so feeble it could lift three times as much as the old one.

The antonym of feeble--effective--was embedded in the same two sentence frames, so that four sentences were generated for each antonym pair. Each sentence was read aloud at least twice, and the child was required to say whether it made sense or not. Before starting the test he was informed that the meanings of unknown words, apart from the test words themselves, would be provided on request. There were three practice sentences, after which the complete set of forty sentences was presented in the same random order to each subject. Although children were not told beforehand what the test word was, they were often able to deduce it as the majority of requests for word meanings concerned the test word itself. When the child encountered a sentence containing an unfamiliar test word he was encouraged to "pass" rather than guess, because, there being only two sentences for each test word, the latter strategy would have lead to chance successes (2/2) in 25% of cases.

Results

Before presenting the results of the comprehension test, it is of interest to note that three instances of spontaneous semantic confusion were recorded during this study. Two of these errors were made by a Group III retarded reader (VIQ = 103; PIQ = 96; Full Scale IQ = 100; CA = 10:10; Reading Age (Accuracy) = 6:8; Spelling Age = 5:1) who wrote come when asked to spell go (Boder Spelling Test) and who also read the word coming as going during the second Neale Analysis (Form A) given at the end of the test program when he was aged 11:7 and his Reading

Age was 7:4. When this type of error occurs in the course of reading or spelling the interpretation is, admittedly, open to question.

The third instance concerned a Group II retarded reader (VIQ = 118; PIQ = 121; Full Scale IQ = 121; CA = 8:11; Reading Age (Accuracy) = 7:9; Spelling Age = 7:0) who produced the following self-corrected error in conversation with the examiner during one of the test sessions:

"My dad promised me he'd be getting me balsa wood last night, but he forgot it. He had to come home early--late, I mean--and the shops were closed."

Slips of the tongue of this kind are not uncommon even amongst adults who are not handicapped by language or learning disorders, and the occurrence of only three recorded instances over a period of 2½ years in which 80 boys spent an estimated 3000 hours engaged in tests makes it difficult to sustain the notion that this phenomenon is related to the reading disorder.

In analysing the results of the comprehension test two measures of performance were employed. One was the number of individual adjectives which the subject understood (max. score = 20), and the other was the number of instances where he understood both the adjective and its antonym (max. score = 10). To demonstrate that he knew the meaning of a given word it was necessary for the subject to produce correct responses to both sentences which contained it. (If an incorrect response was self-corrected by the child, it was nevertheless counted as incorrect.)

Table 5.6 shows the mean number of adjectives and antonym pairs comprehended by the retarded and normal (Verbal control) readers of Groups I, II, and III. An analysis of the results by means of the t test with paired observations showed that in none of the three age ranges was there a significant difference between the two reading ability

groups on either of the two comprehension measures. (The values of t yielded by the six statistical comparisons are shown in the Table.)

The extent to which this comprehension test provides a measure of the child's general vocabulary level may be gauged from the fact that, for the combined sample ($N = 60$), the correlation between the number of individual words comprehended on the former test and the raw score on the Vocabulary subtest of the WISC was 0.72 (Pearson product-moment coefficient).

If semantic confusions do occur in a test of this kind one would expect to find two basic types of error. The first (Type 1) would arise when both members of an antonym pair are interpreted as their opposite, so that the subject makes incorrect responses to all four sentences associated with a given antonym pair. Of course, systematic errors on a set of four sentences do not necessarily indicate that one word has been confused with the other, and vice versa, for they may result from guesswork, or failure to understand the sentence frame. In any event, error patterns of this sort were comparatively rare. Ignoring instances where "pass" responses contributed to the overall result, only four retarded readers (two in Group I, and two in Group II) and three normal readers (one in each Group) made systematic errors in response to one four-sentence set. The other kind of error pattern (Type 2) which might indicate that semantic confusion has occurred arises when the subject appears to understand one word of a pair but makes systematic errors in response to the two sentences containing its opposite. Again not counting "pass" responses, there were 19 instances of this error pattern in the retarded readers' groups (6 in Group I, 11 in Group II, and 2 in Group III) and 21 in the normal readers' groups

(8 in Group I, 6 in Group II, and 7 in Group III). However, a comparison based on the frequency of this error pattern is inconclusive because a proportion of them could merely reflect the fact that one member of the antonym pair is more familiar to the subject than the other. To determine whether this factor had any bearing on which adjective-antonym pairs were subject to Type 2 errors an index of the relative familiarity of words within a pair was formulated in the following way. The frequency of occurrence of each word was determined from the J column of the Thorndike-Lorge word count, and the difference between these two frequencies was expressed as a proportion of their mean value. Or, denoting the frequencies of the two words by f_A and f_B , the index of relative familiarity is given by:

$$I_{AB} = \frac{2(f_A - f_B)}{f_A + f_B}$$

The ten antonym pairs were ranked first in terms of their I-values (without regard to sign), and then according to how frequently they were subject to Type 2 errors. To express the degree of association between these two rankings the Spearman rank correlation coefficient was computed, but the resulting value of rho (0.19) was found to be non-significant. Contrary to what might have been supposed, therefore, the relative frequency of occurrence of an adjective and its antonym does not appear to have a significant bearing on the extent to which that pair is subject to errors in only one term.

The above finding does not necessarily imply that the majority of Type 2 errors were due to semantic confusion. Chance responses could easily account for most, if not all, of them. (If subjects had responded on a chance basis to all 10 antonym pairs the expected

proportion of responses conforming to the Type 2 error pattern would have been 12.5%, or 75 out of the total of 600 four-sentence sets responded to by the complete sample. As reported above, the actual number of Type 2 errors was 40, the difference probably being explained by the fact that children's success rate on individual adjectives (49.6%) was about twice the chance level, so that the number of opportunities for Type 2 errors to occur by chance would be reduced, though by precisely what amount it is difficult to estimate.)

This analysis of error patterns fails because semantic confusions cannot be distinguished from chance responses or genuine lack of knowledge of a word. One approach remaining which might recover something of value from the data is to use the pattern of successes to make inferences about the incidence of adjective-antonym confusions. To this end the child's capacity to resist making semantic confusions may be expressed as the ratio of the number of antonym pairs understood to the number of individual adjectives understood. (The tendency for semantic confusions to occur could have been expressed directly by the inverse of this ratio. However, the reason that this form was not adopted was that in the few instances where the denominator was zero the ratio would have assumed a value of infinity, thus making a statistical analysis of the results impossible.) On comparing the retarded readers' ratios with those of the normal readers (All Groups) by means of the t test (paired observations), it was found that the mean (0.55) obtained by the former group was not significantly different from that (0.58) of the latter ($t = -0.44$, $df = 29$). These results should be treated with caution, being based on a test whose validity has not been properly established, but they suggest that retarded readers are no more likely to confuse the members of antonymous pairs of adjectives than are normal readers.

The retarded readers' results were next examined in greater detail to determine whether there were any differences between Subgroup A (orientation errors present in Schönell Test) and Subgroup B (orientation errors absent). It may be recalled that these two Subgroups achieved significantly different mean scores on the Vocabulary subtest of the WISC. In view of the high correlation between subjects' scores on the Vocabulary subtest and their scores on the comprehension test, it was thought likely that Subgroup A would be inferior to B on the latter test as well. In fact, a comparison by means of the Mann-Whitney U-test showed that the members of Subgroup A ($N = 12$), understood significantly fewer individual adjectives ($p < 0.02$), and also significantly fewer antonym pairs ($p < 0.02$) than Subgroup B ($N = 12$). Moreover, the mean antonym pair/adjective ratio for Subgroup A was 0.44, compared to 0.63 for Subgroup B, though the difference between these mean scores just failed to reach significance ($t = -1.62$, $df = 22$). (Expressing this difference in a slightly different way, Subgroup B understood 1.42 times as many individual adjectives as Subgroup A (10.75 : 7.58), but 1.69 times as many antonym pairs (3.67 : 2.17).)

It is not immediately apparent that the difference in mean ratio between Subgroups A and B is not merely an artifact which reflects their different vocabulary levels. This question was examined by dividing the normal readers into two subgroups, one (N_1) consisting of subjects whose adjective score on the comprehension test was below the median and the other (N_2) whose members scored above. On average Subgroup N_1 understood 7.07 adjectives and obtained an antonym pair/adjective ratio of 0.49, while Subgroup N_2 understood 13.27 adjectives and obtained a mean ratio of 0.69, indicating that, as in the case of the retarded readers, the value of the ratio is not independent of vocabulary level. In the

absence of any substantial evidence to suggest that some normal readers are predisposed to make semantic confusions, the most plausible interpretation of the above figures is that the variation in mean ratio between subgroups is an artifact of their vocabulary level, and that the same is true of the retarded readers. Otherwise, it would have to be concluded that the ratio is a valid measure of children's tendency to make semantic confusions and that it is dependent on vocabulary level, but not on reading ability. However the comprehension test would have to be properly validated before one could be certain about either interpretation.

5.6 Children's knowledge of conventional series

Introduction

Substantial evidence is available from clinical investigations (Bender, 1958; Critchley, 1970; Miles, 1978), classroom observations (Jordan, 1972), and controlled studies (Doehring, 1968) to suggest that many retarded readers have great difficulty in learning and retaining conventional sequences, such as months of the year and letters of the alphabet. The rote learning deficiency is often accompanied by an inability to follow sequences of instructions or to recall past events in the correct order.

As far as is known the acquisition of sequences has not been studied in relation to factors such as the child's linguistic background or classroom teaching methods. However, it seems reasonable to suppose that, as a result of the decline in rote learning methods, this aspect of language acquisition has, over the past two decades, been governed

more by the child's level of intelligence, interest, and motivation than was formerly the case. As a result the success of the process has probably become more dependent on the child's level of reading ability and the availability of classroom materials such as wall charts. Now that the oral method is less widely-used it is difficult to judge whether dyslexics suffer from a basic disorder of auditory sequential memory or whether their difficulty in this respect is secondary to the reading disorder. The first interpretation is probably correct, because these difficulties were first noted at a time when rote learning was given greater emphasis, and also because the associated deficiencies in which there is confusion about the temporal order of events would be unlikely to arise as a consequence of the reading disorder. In practice, it would not be easy to determine how far the acquisition of sequences has been impeded by the child's reading difficulty, and the issue will not be examined directly here. Instead, two other objectives will be pursued. The first is to confirm that retarded readers' rote learning disorder can be demonstrated under controlled conditions, thus bearing out the assumption that it is not part of a more general verbal deficit in which other aspects of language are equally affected. The second aim is to establish whether some retarded readers experience the difficulty in a more severe form than others. If such is the case, it will be of interest to determine first of all whether one subgroup can be distinguished from the other on any of the measures used so far and, secondly, what relationship exists between the composition of these subgroups and that of the two subgroups (A and B) identified earlier.

Procedure and Method of Scoring

The child was asked to enumerate the following sequences (in the order given):

- (1) Days of the week
- (2) Seasons
- (3) Months of the year
- (4) Letters of the alphabet
- (5) Numerals: 1 to 20
- (6) Days of the week, in reverse order
- (7) Months of the year, in reverse order

The first item of each sequence was supplied by the examiner, e.g., "Can you say the days of the week, starting with Monday?" The child's responses were recorded on tape and later transcribed.

It proved more difficult than anticipated to arrive at a method of scoring which could be applied systematically to every protocol. The scheme which was finally adopted is based on the following rationale:

An item in an ordered series may be considered to be in the correct position by virtue of two attributes:

- (a) its position in relation to the preceding item
- (b) its numerical position in the series.

When a series is reproduced correctly both (a) and (b) are satisfied for all items. However, when errors occur scoring decisions based on (a) may not agree with those based on (b). For example, consider the following two series:

- (i) January, April, March.....
- (ii) January, April, February, March.....

In (i) March is in the correct numerical position, but its position following April is incorrect, while in (ii) March is in the correct position following February, but its numerical position is incorrect. It was found by trial and error that fewer scoring problems arise when the position of an item is judged solely in terms of criterion (a). If an item is out of position in the sense defined in (a), the error may be classified in terms of an OMISSION, a TRANSPOSITION, or a REPETITION. The category "Substitution" was not included in this scheme, because, unlike the case of letters in words, "substituted" items in an enumeration of the months, for example, are almost invariably the names of other months, whereas, in spelling a word, letters not occurring in it may be substituted for the correct one(s).

The scheme was applied in the following way. The series was first inspected to determine all OMISSIONS, which were noted and reinserted in the series. Next, the partially reconstructed series was examined item by item until the first out of sequence item (X_1) was found. Denoting the correct item whose position X_1 was occupying by R: if X_1 preceded R in the series and X_1 had already occurred in its correct position or, if omitted, had been supplied by the examiner at the time, then X_1 was counted as a REPETITION. However, if X_1 preceded R in the series and was omitted but not supplied by the examiner at the time, then X_1 was counted as a TRANSPOSITION.

On the other hand, if X_1 followed R in the series and in turn was followed by an item later in the series, and, further, if R occurred later in the series, then R was counted as a TRANSPOSITION when it was subsequently considered, provided that it was not supplied as a correction when the subject produced X_1 . If X_1 followed R and was followed by an item prior to X_1 , or no item, and further if X_1 did not also occur in its correct place, then X_1 was counted as a TRANSPOSITION.¹

These rules were applied within the longest subsequences of items occurring between corrective interventions or promptings by the examiner. As a result of such interventions the subject sometimes recalled an omitted item or produced a correct re-ordering, but the first attempt was the one that was counted for scoring purposes.

Results

Table 5.7 shows the numbers of OMISSIONS, TRANSPOSITIONS, and REPETITIONS incurred in each series by the retarded readers and normal readers (Verbal control) of Groups I, II, and III. Every child gave the numerals correctly, while only three children (two retarded and one normal reader) made errors on the days of the week (forwards). On the remaining series the error rates were high enough to permit statistical comparisons to be made, and the Wilcoxon, matched-pairs, signed-ranks, test (1-tail) showed that a significantly greater number of errors were made by the retarded readers in enumerating the days of the week (reverse order), ($T = 1.5$, $N = 8$, $p < 0.01$), the months of the year ($T = 31.5$,

¹ On these definitions, when the positions of two items were interchanged, e.g., ...f, j, h, i, g, k, ... the error was recorded as two TRANSPOSITIONS (j and g) since either one can occur independently of the other, viz., ...f, g, j, h, i, k, ... or ...f, h, i, j, g, k, ... An exception to this rule was made when the two items interchanged were adjacent, in which case one TRANSPOSITION was recorded.

Table 5.7. Enumeration of conventional series: Mean number of errors (OMISSIONS, TRANSPCITIONS, and REPETITIONS) made by retarded readers and normal readers (Verbal control) of Groups I, II, and III.

	Group I		Group II		Group III	
	RR	NR (VC)	RR	NR (VC)	RR	NR (VC)
Mean CA	9:3	9:3	9:10	9:8	11:5	11:7
Mean no. of errors:						
Days (forward)						
OMISSIONS	0	0.1	0.3	0	0.3	0
TRANSPPOSITIONS	0	0	0	0	0	0
REPETITIONS	0	0	0	0	0.1	0
Days (backward)						
OMISSIONS	0.3	0.1	0.6	0	0.8	0
TRANSPPOSITIONS	0	0	0.1	0	0.2	0
REPETITIONS	0.3	0	0	0	0.2	0
Months (forward)						
OMISSIONS	1.4	1.0	2.0	0.2	2.6	0.2
TRANSPPOSITIONS	0.6	0.2	0.1	0.1	0.6	0.2
REPETITIONS	0.1	0	0	0	0.1	0
Months (backward)						
OMISSIONS	3.4	1.1	3.3	1.0	4.1	0.4
TRANSPPOSITIONS	0.4	0.5	0.3	0.6	0.5	0.3
REPETITIONS	2.0	0.6	0.8	0.3	0.4	0.1
Seasons						
OMISSIONS	0.6	0.2	0.1	0.1	0.7	0
TRANSPPOSITIONS	0.5	0.3	0.3	0.2	0.2	0
REPETITIONS	0.1	0.1	0	0.1	0	0
Alphabet						
OMISSIONS	2.6	0.9	1.1	1.2	2.9	0.2
TRANSPPOSITIONS	0.3	0.2	0.8	0.4	0.2	0
REPETITIONS	0.6	0.2	0.1	0	0.4	0

$N = 21$, $p < 0.01$), the months of the year (reverse order), ($T = 66.5$, $N = 27$, $p < 0.01$), the seasons ($T = 18$, $N = 15$, $p < 0.01$), and the letters of the alphabet ($T = 44.5$, $N = 19$, $p < 0.025$).

With a view to analysing the retarded readers' performance in greater detail, a composite score was formed from the sum of subjects' errors on four series: days of the week, months of the year, seasons, and letters of the alphabet. The retarded readers were then divided into two subgroups, one consisting of 16 boys (Mean CA = 10:4) with error scores in the range 0 to 4, and the other consisting of 14 boys (Mean CA = 9:11) with scores in the range 5 to 22. Had these two subgroups been compared as they were, the former might have exhibited an artificial advantage on certain measures on account of the age difference, and the two eldest boys were therefore eliminated from the larger subgroup, reducing its mean age from 10:4 to 10:1. The retarded readers with poor memory for series were designated as Subgroup C ($N = 14$, Mean CA = 9:11), and those with relatively good memory as Subgroup D ($N = 14$, Mean CA = 10:1).

As may be seen from Table 5.8, Subgroup C was inferior to Subgroup D in respect of Reading Age (Accuracy), Reading Age (Comprehension), Spelling Age, Verbal IQ, Performance IQ, and its scores on seven subtests of the WISC: Similarities, Vocabulary, Arithmetic, Digit Span, Object Assembly, Picture Completion and Coding. When these differences in intellectual ability are taken into account, the two Subgroups were more closely matched in the acquisition of spatial concepts than one might have expected (Table 5.9). Although Subgroup D was more advanced than C in the comprehension of above-below relations, they were at comparable stages of development in the acquisition of the other two projective relations and in their conceptions of the horizontal and vertical.

Table 5.8. Intellectual ability and reading and spelling attainment in retarded readers: A comparison of subjects who made four or more errors in enumeration of series (Subgroup C, N = 14) and subjects who made less than four errors (Subgroup D, N = 14).

	Subgroup C		Subgroup D		t test (1-tail)	
	Mean	SD	Mean	SD	Value	Sig. Level
CA ¹	9:11	0:11	10:1	0:10	-0.46	NS
VIQ	104	10	115	9	-3.13	p<0.01
PIQ	109	8	120	10	-3.14	p<0.01
Verbal Scale:						
Similarities	14.1	1.4	15.8	2.0	-2.54	p<0.01
Vocabulary	11.4	2.6	12.9	2.0	-1.72	p<0.05
Arithmetic	9.4	2.2	11.1	2.8	-1.83	p<0.05
Digit Span	7.5	2.0	9.7	1.9	-2.95	p<0.01
Performance Scale:						
Block Design	12.5	3.5	13.8	3.4	-0.99	NS
Object Assembly	12.4	2.3	14.5	2.2	-2.46	p<0.05
Picture Completion	10.9	2.7	12.5	2.0	-1.84	p<0.05
Picture Arrangement	11.1	2.1	12.3	2.6	-1.37	NS
Coding	9.6	2.3	11.2	2.5	-1.72	p<0.05
RA (Acc)	7:2	0:7	8:3	0:6	-5.35	p<0.001
RA (Comp)	7:10	0:11	9:0	1:1	-3.59	p<0.01
SA	6:6	0:10	7:7	0:7	-3.64	p<0.01
AQ	73.3	6.5	74.2	3.8	-0.47	NS

¹ CA at time of series test.

Table 5.9. Retarded readers' conception of (a) projective relations and (b) the vertical and horizontal: A comparison of subjects who made four or more errors in enumeration of series (Subgroup C, N = 14) and subjects who made less than four errors (Subgroup D, N = 14).

Stage	Subgroup C	Subgroup D	Fisher Exact Probability test (1-tail)
Left-right relations			
O-IB	4	2	p = 0.24
II	$\frac{9}{1}$	$\frac{7}{2}$	
III	$\frac{1}{0}$	$\frac{2}{2}$	
Uncl.	0	2	
Above-below relations			
O-IB	1	1	p = 0.03
IC	$\frac{10}{2}$	$\frac{5}{8}$	
III	$\frac{2}{1}$	$\frac{8}{0}$	
Uncl.	1	0	
Further-nearer relations			
O-IB	1	3	p = 0.27
IC	$\frac{11}{1}$	$\frac{6}{3}$	
III	$\frac{1}{1}$	$\frac{3}{2}$	
Uncl.	1	2	
Horizontal/Straight-sided/Pre-D			
IIA/B-IIIA	5	2	p = 0.19
IIIA	$\frac{8}{1}$	$\frac{10}{2}$	
IIIB	1	2	
Horizontal/Straight-sided/Post-D			
IIA/B-IIIA	2	0	p = 0.19
IIIA	$\frac{10}{2}$	$\frac{9}{5}$	
IIIB	$\frac{2}{2}$	$\frac{5}{5}$	
Horizontal/Round-bottom/Pre-D			
IIA/B-IIIA	3	4	p = 0.50
IIIA	$\frac{6}{5}$	$\frac{6}{6}$	
IIIB	5	4	
Horizontal/Round-bottom/Post-D			
IIA/B-IIIA	0	1	p = 0.50
IIIA	$\frac{4}{4}$	$\frac{1}{2}$	
IIIB	10	11	
Vertical/Straight-sided/Pre-D			
IIA/B-IIIA	4	3	p = 0.50
IIIA	$\frac{7}{3}$	$\frac{9}{2}$	
IIIB	3	2	
Vertical/Straight-sided/Post-D			
IIA/B-IIIA	0	1	p = 0.32
IIIA	$\frac{12}{2}$	$\frac{9}{4}$	
IIIB	$\frac{2}{2}$	$\frac{4}{4}$	

Subgroups C and D were also compared, on the above measures, with their respective controls. This analysis (Table 5.10) showed that, whereas Subgroup C was significantly inferior to its control group in respect of Verbal IQ and WISC Vocabulary and Digit Span scores, Subgroup D's performance did not differ significantly from that of its control on any of the measures examined.¹

Subgroups C and D were also compared with their respective Performance controls with regard to the acquisition of euclidean concepts. Table 5.11 shows the numbers of subjects at each developmental stage on the three axes of reference tests. Within each subgroup, a Wilcoxon, matched-pairs, signed-ranks, test was used to compare the numbers of correctly oriented lines (max. score = 7) produced by the retarded readers and their controls on each task (Pre- and Post-D). It was found that neither subgroup's performance differed from that of its control on any of the tests.

Considering next the acquisition of projective relations, Table 5.12 shows the distribution of subjects in Subgroups C and D and the control subgroups with respect to their level of comprehension of left-right, above-below and further-nearer relations. A comparison, by means of the Fisher exact probability test, showed that subjects in Subgroup C

¹ The fact that Subgroup C's Vocabulary score was significantly lower than that of its control requires explanation in view of the strict criterion employed in matching the verbal abilities of retarded and normal readers. During the selection procedure it was often difficult to find control subjects, particularly in Group III, whose Maxwell Verbal Scores were as low as those of the retarded readers. Consequently the majority of those finally selected had scores which, although within the chosen tolerance, were higher than those of the retarded readers, whereas in matching non-verbal abilities, control subjects' scores were distributed above and below those of the retarded readers in roughly equal numbers. Thus Subgroup C's performance reflects the fact that there is a progressive decline in the verbal abilities of some retarded readers.

Table 5.10. Intellectual abilities in Subgroups C (N = 14) and D (N = 14) of the retarded readers: A comparison with their respective control groups by means of the t test (paired observations).

	RR		NR		t test (2-tail)	
	Subgroup C		Controls of Subgroup C		Value	Sig. Level
	Mean	SD	Mean	SD		
CA	9:11	0:11	9:11	0:11	-0.20	NS
VIQ	104	10	112	7	-3.99	p<0.01
PIQ	109	8	110	13	-0.38	NS
Verbal Scale:						
Similarities	14.1	1.4	14.2	1.4	-0.37	NS
Vocabulary	11.4	2.6	12.4	1.9	-2.55	p<0.05
Arithmetic	9.4	2.2	10.9	1.8	-2.03	NS
Digit Span	7.5	2.0	10.1	2.6	-3.15	p<0.01
Performance Scale:						
Block Design	12.5	3.5	12.6	3.1	-0.10	NS
Object Assembly	12.4	2.3	12.1	3.4	0.36	NS
Picture Completion	10.9	2.7	11.3	3.2	-0.33	NS
Picture Arrangement	11.1	2.1	10.7	3.2	0.41	NS
Coding	9.6	2.3	10.4	3.6	-0.67	NS

	RR		NR		t test (2-tail)	
	Subgroup D		Controls of Subgroup D		Value	Sig. Level
	Mean	SD	Mean	SD		
CA	10:1	0:10	10:1	1:2	00.17	NS
VIQ	115	9	118	12	-1.28	NS
PIQ	120	10	122	15	-0.67	NS
Verbal Scale:						
Similarities	15.8	2.0	16.0	1.6	-0.71	NS
Vocabulary	12.9	2.0	12.6	1.8	1.07	NS
Arithmetic	11.1	2.8	12.3	2.1	-1.28	NS
Digit Span	9.7	1.9	10.5	3.2	-1.12	NS
Performance Scale:						
Block Design	13.8	3.4	14.6	3.5	-1.17	NS
Object Assembly	14.5	2.2	13.8	2.2	0.93	NS
Picture Completion	12.5	2.0	11.5	3.3	1.15	NS
Picture Arrangement	12.3	2.6	13.3	3.3	-0.77	NS
Coding	11.2	2.5	12.4	2.5	-1.67	NS

For Note see following page ...

Note to Table 5.10.

In the above comparisons the normal readers group was composed of either Verbal or Performance controls, depending on the nature of the test. The comparison of mean ages involved the Verbal control group.

Table 5.11. The acquisition of euclidean concepts: Subgroups C (N = 14) and D (N = 16) compared with their respective controls in terms of the numbers of subjects at each developmental stage. (The statistical test (Wilcoxon) is based on the subject's raw score, i.e., the number of correctly oriented lines produced on each test.)

Stage	RR Subgroup C	NR PC for Subgroup C	RR Subgroup D	NR PC for Subgroup D
Horizontal/Straight-sided/Pre-D				
IIA/B-IIIA	5	7	2	4 4
IIIA	8	7	10	1010
IIIB	1	0	4	2
$z = -0.28, p = 0.39$ (1-tail) $z = -1.17, p = 0.24$ (2-tail)				
Horizontal/Straight-sided/Post-D				
IIA/B-IIIA	2	1	0	0
IIIA	10	11	9	12
IIIB	2	2	7	4
$z = 0.18, p = 0.43$ (1-tail) $z = -0.25, p = 0.80$ (2-tail)				
Horizontal/Round-bottom/Pre-D				
IIA/B-IIIA	3	6	4	6
IIIA	6	2	6	4
IIIB	5	6	6	6
$z = -0.87, p = 0.19$ (1-tail) $z = -1.08, p = 0.28$ (2-tail)				
Horizontal/Round-bottom/Post-D				
IIA/B-IIIA	0	0	1	0
IIIA	4	7	2	5
IIIB	10	7	13	11
$z = -1.15, p = 0.13$ (1-tail) $z = -0.52, p = 0.60$ (2-tail)				
Vertical/Straight-sided/Pre-D				
IIA/B-IIIA	4	6	3	4
IIIA	7	7	11	9
IIIB	3	1	2	3
$z = -0.20, p = 0.42$ (1-tail) $z = -0.48, p = 0.63$ (2-tail)				
Vertical/Straight-sided/Post-D				
IIA/B-IIIA	0	7	1	2
IIIA	12	6	11	10
IIIB	2	1	4	4
$z = -0.63, p = 0.26$ (1-tail) $z = -0.20, p = 0.84$ (2-tail)				

Note: A 2-tail region of rejection was adopted for the statistical tests used to compare Subgroup D (but not C) with NR(PC) as no prediction was made about the direction of the difference.

Table 5.12. The acquisition of projective relations: Subgroups C (N = 14) and D (N = 16) compared with their respective controls in terms of the numbers of subjects at each developmental stage (Fisher exact probability test).

Stage	RR Subgroup C	NR VC for Subgroup C	NR PC for Subgroup C	RR Subgroup D	NR VC for Subgroup D	NR PC for Subgroup D
Left-right relations						
O-IB	4	4	3	2	1	1
II	9	2	6	8	10	7
III	1	7	5	4	5	6
Uncl.	0	1	0	2	0	2
		p = 0.01	p = 0.08		p = 1.00	p = 0.69
Above-below relations						
O-IB	1	1	1	1	1	0
IC	10	4	5	6	9	8
III	2	9	8	9	5	8
Uncl.	1	0	0	0	0	0
		p = 0.01	p = 0.03		p = 0.48	p = 1.00
Further-nearer relations						
O-IB	1	2	1	3	4	3
IC	11	7	9	8	7	10
III	1	4	3	3	5	3
Uncl.	1	1	1	2	0	0
		p = 0.16	p = 0.30		p = 0.85	p = 1.00

Note. A 2-tailed region of rejection was adopted for the statistical tests used to compare Subgroup D (but not C) with NR(VC) and NR(PC) as no prediction was made about the direction of the difference.

were significantly retarded in the acquisition of both left-right and above-below concepts relative to the Verbal control subgroup, but were no different from the controls in the comprehension of further-nearer relations. In contrast, Subgroup D and its Verbal control subgroup were at comparable stages of development in the acquisition of all three concepts. The pattern of results was similar when Subgroups C and D were compared with their respective Performance control subgroups, except that the difference between Subgroup C and its controls in the comprehension of left-right relations fell just short of significance.

5.7 Discussion

An assessment of oral language showed that retarded readers are no different from normal in two aspects of syntactic development, namely their comprehension of sentence structures which involve exceptions to the Minimum Distance Principle, and their implicit knowledge of word classes. Furthermore, Subgroup A (orientation errors present) and B (orientation errors absent) achieved comparable levels of performance on these two syntactic measures, an outcome which was not altogether predictable in view of the earlier finding that they differed in vocabulary level. While it cannot be claimed that this assessment was exhaustive, the results tend to support the conclusions of Doehring (1968) and Fry, Muehl and Johnson (1970) that, in most respects, retarded readers' oral language development is not exceptional, any deficiencies being confined to a relatively small number of structures.

In the next stage of the investigation, evidence was sought for the presence of two specific linguistic deficiencies which have been reported

to occur in some retarded readers. The first to be investigated was their supposed tendency to substitute an antonym for the correct adjective, adverb, or verb. Using a set of relatively unfamiliar adjective-antonym pairs, a comprehension test was designed for the purpose of eliciting semantic confusions, the tendency to produce such errors being expressed as the ratio of the number of individual adjectives from this set in the child's vocabulary to the number of adjective pairs. This index was not formally validated, and the interpretation of the results is therefore open to question, but on the face of it the occurrence of semantic confusions was not related to children's reading level. In fact, vocabulary level appeared to be a more important factor in determining the magnitude of the index, though again this finding is inconclusive insofar as it could be due to an interaction between the child's vocabulary level and the variation in the relative familiarity of words within adjective-antonym pairs.

Though the comprehension test failed to fulfill its main purpose in a convincing manner, the results were not entirely without value, in that they supported the earlier finding that Subgroups A and B differ in vocabulary level. (This conclusion might be disputed on the grounds that comprehension of the test sentences involves more than knowledge of the embedded adjectives, but a highly significant proportion of the variance of oral comprehension scores was accounted for by vocabulary. and, furthermore, there was no evidence that differences in syntactic ability played a part in the outcome.)

In contrast to the negative findings concerning semantic confusions, there was definite evidence to support the frequently reported observation that some retarded readers experience considerable difficulty in retaining common series. Thus, in their ability to recall the days of the week

(backward), the months of the year (forward and backward), the seasons, and the letters of the alphabet the retarded readers were markedly inferior to the normal readers. Moreover, those retarded readers who evinced the greatest degree of difficulty (Subgroup C) exhibited specific verbal and conceptual deficiencies in relation to their control subjects, whereas those with better recall (Subgroup D) reached the same level of performance as their controls on all the measures examined. Thus, Subgroup C was inferior to its control group in respect of Verbal IQ, vocabulary, auditory short term memory (Digit Span subtest of the WISC), and knowledge of left-right and above-below (but not further-nearer) relations.

Had the retarded readers of Subgroup C not obtained a significantly lower vocabulary score than their control subjects, there would have been a strong case for arguing that their poor knowledge of sequences constitutes a specific verbal deficiency, particularly as the two groups' syntactic abilities were equally well developed.¹ But since subjects' knowledge of sequences was not referred to a normative scale it is difficult to say whether Subgroup C's weakness in this area is more pronounced than its vocabulary deficiency, and one cannot be certain, therefore, that the former impairment is not merely one component of the latter, though as far as can be determined just from inspection of the data this explanation does not seem very likely. Moreover, the difference in Digit Span score between Subgroup C and its control group

¹ On the word association test, the mean number of homogeneous responses produced by Subgroup C (N = 14) was 11.29, a score which was not significantly different from the mean (10.93) obtained by the Verbal control group (N = 14) ($t = 0.23$, $df = 13$). Similarly, in their comprehension of Chomsky's five syntactic structures, Subgroup C (mean score = 2.86) did not differ significantly from the Verbal control group (mean score = 2.77) (Wilcoxon test: $T = 17.5$, $N = 8$).

was more pronounced than the difference in vocabulary score (see Table 5.10), suggesting that the acquisition of series is more dependent on auditory short-term memory than on general vocabulary level.

When the distribution of retarded readers within Subgroups A, B, C, and D was examined it was found that there is an association between inferior knowledge of series and the propensity to make orientation errors, as the following table demonstrates:

	Subgroup A	Subgroup B	Uncl.
Subgroup C	9	4	1
Subgroup D	4	11	1

$$(X^2 = 3.51, p < 0.05, 1\text{-tail})$$

Despite the relatively large number of retarded readers common to Subgroups A and C, the smaller number of subjects who belonged to only one or other had a marked influence on the relative performance of Subgroups C and D, when compared with that of Subgroups A and B. Thus, the difference in Performance IQ between A (PIQ = 113) and B (PIQ = 114) was negligible, whereas that between C (PIQ = 109) and D (PIQ = 120) was highly significant. Similarly, there was a non-significant difference in Digit Span score between A (8.3) and B (8.0), but a highly significant difference between C (7.5) and D (9.7). A more detailed analysis of the characteristics of the four Subgroups will be undertaken in the concluding chapter.

Chapter 6

6.1 Introduction

The aim of the work described in this Chapter is to investigate the processes governing the acquisition of common series, and their relationship to the reading process. It was proposed in Chapter 1 that the limited knowledge of series in some retarded readers might be a consequence of the fact that they do not have access to an imaginal spatial framework. This explanation is consistent with a model of serial learning proposed by Ebenholtz (1963a, b), who demonstrated experimentally that the acquisition of serial lists by normal adults is mediated in part by knowledge of the spatio-temporal positions of the component items. The findings described in the previous chapter provide limited support for the above interpretation insofar as the retarded readers with poor memory for series (Subgroup C) were less advanced in their conception of above-below (but not left-right or further-nearer) relations than those with relatively sound knowledge (Subgroup D). When compared with their controls, members of Subgroup C were retarded in the acquisition of both left-right and above-below concepts, whereas Subgroup D did not differ from its control group on any of the measures pertaining to projective relations. At the same time, both subgroups were as advanced as their respective control groups in their conceptions of the horizontal and vertical. Thus, if serial learning is facilitated through a process whereby items are assigned to locations on the vertical axis of an imaginal frame of reference, the original hypothesis would appear to be sustained in a modified form.

The experimental findings summarized above tend to confirm the theoretical predictions, but the extent to which Subgroups C and D differ in their comprehension of above-below relations, while significant in statistical terms, scarcely seems of sufficient consequence to account for the difference in their knowledge of series. Moreover, Subgroup C was inferior to D in a number of other respects, and it may be premature, therefore, to rule out alternative interpretations. One area of development in which Subgroup C was less advanced than D was vocabulary, suggesting that the difficulty may not be one of retaining information about the correct order of items, but of storing or retrieving the items themselves. This consideration may assume some significance in the case of series such as the months of the year, where the elements differ from the majority of words in the child's vocabulary in that the denotative and derivational meanings are abstract (the former being based on the ordering relation itself, i.e., the n^{th} month of the year, where $n = 1, 2, \dots, 12$), while the connotative meanings are unstable and subjective.

Secondly, the capacity of auditory short-term memory was found to be more limited in Subgroup C by comparison both with its control group and with Subgroup D. Now, considering the problem in terms of the dual-storage model of memory, the imaginal spatial framework is presumed to subserve the organization of serial information in secondary memory. In certain circumstances a visuo-spatial array may be used to represent ordering relations in primary memory - for example, in reasoning about logical propositions (Inhelder and Piaget, 1964; DeSoto, London, and Handel, 1965; Handel, DeSoto, and London, 1968),

or simply as a characteristic mode of thinking about relations between elements of common series by those individuals who possess "number forms" (Galton, 1907; Oswald, 1960). Nevertheless, it is doubtful whether children would adopt such a strategy in learning series, since the usual form of encoding employed for the rehearsal of verbal items in primary memory is an acoustic-articulatory one; no other form of encoding would be readily available for items of this degree of abstractness. If, as the findings suggest, the acquisition of series is impeded by a deficiency in short-term memory, and the above analysis in terms of the dual-storage model is correct, it would imply that learning is impeded at a stage prior to that at which the imaginal spatial framework is brought into play.

Thus, retarded readers' poor memory for sequences can be interpreted in more ways than one, and in order to give due weight to all the factors which might be involved it may well be necessary to adopt a theoretical framework broader than that so far used. A theoretical model which is more comprehensive, yet does not necessarily exclude the position-mediated process, has been put forward by Paivio (1971), who sought to explain the significance of verbal and imaginal processes in learning and memory through an analysis of the ways in which performance is related to various semantic attributes of the items making up the list. The principal stimulus attributes which he believes to influence performance on memory tasks are: (1) abstractness-concreteness (C), defined as the degree to which an object or concept can be experienced by the senses, (2) imagery (I), defined in terms of the ease with which the word arouses a mental image, (3) verbal associative meaningfulness (m), representing the likelihood of a word

evoking verbal associations, and (4) familiarity, or frequency of occurrence. (In the most extensive study so far carried out, Paivio, Yuille, and Madigan (1968) obtained normative data on C, I, and m for 925 nouns by means of group scaling procedures. Each word was rated by a group of university students on a 7-point abstractness-concreteness scale and a 7-point high-imagery-low-imagery scale, while m was determined by requiring subjects to produce as many written associates of the word as they could in 30 seconds. The correlations between the three parameters for the sample of 925 words were as follows: I and C, 0.83; I and m, 0.72; C and m, 0.56. As far as is known, no studies have been conducted in which younger subjects have been employed as judges, but one would expect the effective values of the parameters to be different for children.)

The relative effects of these four parameters vary according to the type of memory task being performed. For example, the influence of a change in I relative to an equivalent change in m is greatest in paired-associate learning, less in free recall, and least in serial recall. In other words, the potency of m is greatest in serial recall, though even here it is only equal to that of I. This finding suggests that the ease with which associations are formed between one item of an ordered series and the next may be a function of how many associates the two items have in common, which would, in turn, depend on the meaningfulness of each item. Now a study by Reynolds and Paivio (1968), involving adult subjects, has shown that individual differences in the mean value of m obtained for a given set of words are related to differences in oral vocabulary level. If the same relationship holds true for children, and if the associative process does in fact conform to the above description, then one would expect to find a correlation between serial learning performance and vocabulary level.

The results reported in the previous chapter support this deduction insofar as the retarded readers with poor memory for sequences knew fewer words than those with relatively good memory, and they were also inferior to the controls, despite the efforts made to ensure that vocabulary levels were matched. Although it would seem reasonable to suppose that paired-associated learning is mediated by a similar process, it has been demonstrated that changes in m have a negligible effect on performance in this type of task (Paivio, Smythe, and Yuille, 1968). To explain this finding it has been suggested (Underwood and Shulz, 1960) that the associative process could generate incorrect associations and hence interfere with learning, but if this interpretation is correct it is not clear why serial learning would not be liable to the same kind of interference.

Although the verbal and non-verbal learning abilities of retarded and normal readers have been compared in a number of studies, none of the work appears to have been based on the theoretical model formulated by Paivio. Of those employing the paired-associates task (Brewer, 1967; Steger, Vellutino, and Meshoulam, 1972; Vellutino, Harding, Phillips, and Steger, 1975; Vellutino, Steger, Harding, and Phillips, 1975; Vellutino, Steger, and Pruzek, 1973; Zigmond, 1966) the majority show that retarded readers perform equally well on non-verbal tasks, but less well on verbal tasks, when compared with normal readers. As far as serial learning is concerned, a recent review by Torgesen (1978), albeit a selective one, indicates that most studies have been concerned with sequential recall from short-term memory; at least, none of the studies which he describes investigated the acquisition of a list of items over repeated trials. The

research summarized by Torgesen includes both psychometric and experimental studies. Most of the data in the former category consists of performance profiles of retarded and normal readers obtained using the Wechsler Intelligence Scale for Children (WISC) or the Illinois Test of Psycholinguistic Abilities (ITPA), the measure of short-term memory being provided either by the Digit Span subtest, in the case of the WISC, or the Auditory Sequential Memory and Visual Sequential Memory subtests, in the case of the ITPA. Of 27 studies based on the WISC, 16 reported that the immediate memory span of retarded readers was shorter than that of normal readers (none reported a difference in the opposite direction). Studies based on the ITPA appear to be less numerous; of the three cited by Torgesen, two found a deficiency in auditory, but not visual, sequential memory; while the third reported the opposite pattern of results.

In reviewing experimental work on serial memory, one of Torgesen's aims was to evaluate the significance of the findings in relation to current theoretical models, and to this end he organized the research into three categories: (1) studies concerned with structural features of memory, (2) studies relating to control processes, and (3) studies which overlapped categories (1) and (2), or else lacked a well-defined theoretical basis. Research on structural aspects of memory has shown that there are significant differences between retarded and normal readers in respect of (a) search time within auditory and visual short-term memory (Farnham-Diggory and Gregg, 1975), (b) speed of speech-motor encoding, a factor which is believed to have a bearing on the time available for rehearsal (Spring and Capps, 1974), and (c) the efficiency of "short-term language encoding", as determined by performance on a

task in which the subject listened to a series of sentences and then, for each one, attempted to recall an individual word which followed a probe word supplied by the examiner (Perfetti and Goldman, 1976). Studies concerned with the role of control processes suggest that there is an association between the level of reading skill and the use of certain mnemonic strategies. In particular, retarded readers have been shown to be less proficient than normal readers in (a) the use of verbal labelling and/or rehearsal in encoding both temporal (Blank and Bridger, 1966; Blank, Weider, and Bridger, 1968) and spatial (Corkin, 1974) patterns of visual information, (b) the use of verbal labelling and rehearsal in the recall of sequentially presented pictorial information (Tarver, Hallahan, Kauffman, and Ball, 1976; Torgesen and Goldman, 1977), (c) the use of categorical structures as an aid to recall (Parker, Freston, and Drew, 1975; Torgesen, 1977). Studies which, according to Torgesen, do not fit into either of the preceding categories include those by (a) Noelker and Schumsky (1973) and Mason, Katz, and Wicklund (1975) showing that, in tasks involving the reconstruction of sequences of geometric forms and lower-case letters, memory for order is more strongly related to reading ability than is item memory, (b) Koppitz (1970, 1973, 1975), who found that the extent to which retarded and normal readers differ in short-term memory for digit sequences is a function of the modes of presentation and response, and (c) Richie and Aten (1976), who showed that retarded readers are less able than normal readers in the recall of auditory sequences, whether these are composed of non-verbal elements (patterns of tone pulses, varying in duration and inter-pulse interval) or verbal items (words and sentences). (Sequences containing words were

of two types: maximal phonemic similarity (e.g., man, can, fan, pan) and minimal phonemic similarity (e.g., car, boat, dog, cat); Ritchie and Aten found that it was only on the former task that the performance of the retarded readers was inferior to that of the normal readers.)

Thus, as far as can be determined from Torgesen's review, the relationship between long-term serial memory and reading ability has yet to be investigated, although it would appear to be an issue that merits some attention, in view of the fact that retarded readers frequently encounter difficulty in the acquisition of common series. Of course, the latter process could equally well be impeded by a deficiency in short-term memory, though here again none of the studies reported so far appears to have examined this issue. It is also apparent from Torgesen's review that none of the work on the relationship between reading ability and sequential recall has been conducted within the kind of theoretical framework provided by Paivio's model, so that, in adopting his approach, there is no evidence available to indicate which dimensions of meaning have the greatest influence in determining the association between reading ability and sequential memory.

In summary, there is no clear evidence as to which process, or processes, is implicated in the serial learning difficulty found in some retarded readers. For this reason, and also because methodological difficulties were encountered in attempting to realize an adequate design, the experiment which is about to be described should be regarded as exploratory in nature.

6.2 Serial verbal learning, as a function of word meaningfulness and in relation to reading ability and knowledge of common series.

Introduction

It will be recalled that in the sample of retarded readers under study poor knowledge of sequences was associated with inferior performance on measures which are either purely verbal (vocabulary and short-term memory for sequences of digits) or involve a verbal component (comprehension of projective relations), and these findings suggested that it might be expedient to investigate the role of the associative process before attempting a direct evaluation of the spatio-temporal position hypothesis, particularly as the effect of variation in word meaningfulness (m) on serial acquisition is known to be at least as pronounced as that produced by changes in the other parameters. Accordingly, in the experiment described below, an attempt was made to determine whether variations in word meaningfulness have a differential effect on the rates of serial acquisition in children with poor knowledge of common series and those with relatively good knowledge. In fact, it is doubtful whether the design is capable of providing a satisfactory solution to this problem, but the question of its appropriateness in relation to the stated aim assumes less significance in the light of the actual results obtained. Although the latter proved difficult to interpret in terms of Paivio's model, it is believed they are not without interest, if only as the empirical basis for further inquiry.

One of the difficulties encountered in assessing the effect of changes in a particular attribute on serial acquisition is that of maintaining the other parameters constant as far as possible. Lists

satisfying this requirement can be constructed for the assessment of adult performance (Paivio, Yuille, and Rogers, 1969), but in order to test children a considerable proportion of the words in Paivio, Yuille, and Madigan's list have to be excluded on account of their relative unfamiliarity. Thus, if the pool of words is restricted to those of frequency A or AA in the Thorndike-Lorge word count, and if word length is also restricted, it is not possible to control more than one variable at a time. For example, if familiarity is held constant m cannot be varied over a useful proportion of its range without concomitant changes in I . However, it is possible to extend the range over which the effects of m are measured, while keeping the effects of changes in I to a minimum, by using lists composed of nonsense syllables. By comparison with familiar concrete words, this type of verbal element is probably more capable of simulating the semantic attributes of the days of the week and months of the year, at least as they would be perceived by the child on first encounter.

The above approach relies on the work of Noble (1961) who used a rating technique, instead of the production method used in the case of m , to specify the meaningfulness of all 2100 CVC combination of the alphabet. His index of scaled meaningfulness (m') is based on group ratings, on a 5-point scale, of the number of associations a given CVC trigram evokes. Noble, Showell, and Jones (1966) showed that the speed of acquisition of CVC lists in a serial learning task is proportional to the mean value of m' . Since the association value a (the relative frequency of subjects in the standardisation group who report at least one association to the CVC) was held constant at or near the upper end of the scale, a significant number of real words would have

been included. Moreover, those at the upper end of the m' scale would have included a relatively greater proportion of high frequency concrete words than those at the lower end, so that m' was almost certainly confounded with familiarity and imagery (I). In the experiment described below the lists were composed solely of nonsense syllables, thus allowing the effect of m' on acquisition rate to be determined under conditions in which the potentially confounding influence of I is minimal.¹

Procedure

Serial learning performance was investigated by means of two orally presented lists of words in which m and I varied simultaneously, while familiarity and word lengths were controlled, and two lists of nonsense syllables in which m' varied while word length was controlled. Each of the first two lists comprised 10 two-syllable nouns drawn from Paivio et al.'s (1968) sample. One list (R1) consisted of high m nouns (e.g., forest, apple, diamond) for which the mean values of m , I and C were 7.93, 6.39, and 6.36 respectively, and the other (R2) comprised nouns of intermediate m (e.g., excuse, idea, method) for which the mean values of the same three parameters were 5.11, 4.07, and 4.01. The mean frequency of occurrence of nouns in the two lists, as given by

¹ The meaningfulness of nonsense syllables is assumed to derive from words which they connote or form a part of, and these verbal associations are presumably capable of evoking images. However, although there is no direct evidence bearing on the issue, the occurrence of imagery is not thought to be a common associative reaction to nonsense syllables, unless specific instructions to this effect have been given (Paivio, 1971). Therefore, the range of variation of m' within a given set of nonsense syllables is likely to be considerably greater than the variation in I across the same set.

the J Column of the Thorndike-Lorge word count, was 465.6 per 4.5 million for list R1 and 465.4 per 4.5 million for list R2. In addition, there was a 10-item practice list (R0) of two-syllable adjectives whose mean frequency was 463.5 per 4.5 million. (Information on m, I, and C is not available for words in this list.) In compiling the lists of real words Noble's (1952a) rules were observed, except that rule (a) was violated in one instance in list R1 where two (non-adjacent) words had identical final syllables.

Two further 10-item lists were constructed from nonsense syllables drawn from the sample of 2100 CVC trigrams for which Noble (1961) obtained data on association value (a) and scaled meaningfulness (m'). One list (N1) consisted of high m' monosyllables ($\bar{m}' = 3.33$), and the other (N2) consisted of low m' monosyllables ($\bar{m}' = 1.35$). In addition, there was a practice list (NO) of 10 nonsense disyllables drawn from the list of 96 disyllabic paralog and nouns for which Noble (1952b) obtained data on 60-second m. The mean value of m for list NO was 1.30. Lists N1 and N2 were constructed in accordance with modified Muller-Schumann rules (Woodworth, 1938).

In the preliminary stage of the learning procedure the examiner recited the list of items twice, the subject repeating each item before the next one was presented. Thereafter, learning proceeded by means of the anticipation method, incorrect or omitted items being supplied by the examiner. As defined in the instruction given to the child, the goal was to produce one perfect anticipation of all 10 items. However, this criterion was relaxed if the child had not succeeded by trial 30 (though a few subjects went as far as trial 50), or if he found the task too onerous and wished to stop before reaching trial 30. A less

demanding procedure was used in the case of the practice list of nonsense syllables in that all subjects stopped at trial 10, if they had not achieved success by that point, which very few had.

A response was counted as incorrect if it was (a) mispronounced, (b) the result of a self-corrected error, or (c) correct, but had been anticipated in two or more positions immediately preceding it. Real word lists were learned before nonsense syllable lists, but within each category the order of presentation was counterbalanced. In the event that more than one list was given at the same session, they were not learnt consecutively but separated by a different type of test. The serial learning tasks were performed by the retarded readers and their Verbal controls, except for one Group I retarded reader who, having attempted lists RO and R1, was reluctant to try the rest.

Results

For the purposes of analysis, serial acquisition performance was expressed in two ways: first, in terms of the number of items recalled in the correct position on the first trial, and secondly, in terms of the overall rate at which items were acquired, i.e., the number of items learnt by the last trial, divided by the total number of trials which the subject attempted. The mean value of these two measures were calculated for each list, as shown in Table 6.1. As noted above, data for one retarded reader in Group I were missing, and the results obtained by his control were therefore excluded as well, thereby reducing the size of both groups from 11 to 10.

Table 6.1 Serial lists: Acquisition rate (items/trial) on first trial and over all trials for retarded readers and normal readers (Verbal control) of Groups I (N = 10, RR and NR), II (N = 9, RR and NR), and III (N = 10, RR and NR).

	Group I		Group II		Group III		All Groups	
	RR	NR (VC)	RR	NR (VC)	RR	NR (VC)	RR	NR (VC)
Mean CA ¹	9:11	9:9	10:5	10:1	11:10	11:11	10:8	10:7
Acquisition Rate								
Real Words								
RO (Practice Adj.)								
First Trial	2.10	3.00	2.44	2.89	2.44	2.80	2.32	2.90
All Trials	0.88	1.02	0.64	1.52	0.79	1.27	0.77	1.26
R1 (High m Nouns)								
First Trial	2.80	4.20	3.78	4.44	3.70	4.60	3.41	4.41
All Trials	1.66	1.67	1.94	1.95	1.49	1.71	1.69	1.77
R2 (Med. m Nouns)								
First Trial	1.90	2.00	1.89	3.22	1.40	2.20	1.72	2.45
All Trials	0.59	1.32	0.79	1.48	0.51	1.08	0.62	1.29
Nonsense Words								
NO (Practice)								
First Trial	0.40	0.60	0.44	0.67	0.60	0.90	0.48	0.73
All Trials	0.38	0.55	0.49	0.64	0.37	0.61	0.42	0.60
N1 (High m' Syll.)								
First Trial	0.80	1.40	0.44	2.78	1.40	2.40	0.90	2.17
All Trials	0.42	0.72	0.48	0.90	0.52	0.88	0.47	0.83
N2 (Low m' Syll.)								
First Trial	0.70	1.80	0.56	1.67	0.60	0.80	0.62	1.41
All Trials	0.34	0.61	0.29	0.56	0.31	0.64	0.31	0.60

¹ Mean CA at time List NO was given.

Table 6.2 ABCD summary table for four-factor (Reading Ability (A) x Knowledge of Series (B) x Word Meaningfulness (C) x Trial Number (D)) experiment, showing cell means (transformed scores).

		c ₁		c ₂		c ₃		c ₄	
		d ₁	d ₂	d ₁	d ₂	d ₁	d ₂	d ₁	d ₂
a ₁	b ₁	0.6965	0.4196	0.3919	0.1696	0.2123	0.1405	0.1660	0.1144
	b ₂	0.5478	0.4297	0.4049	0.2352	0.2402	0.1830	0.1757	0.1188
a ₂	b ₁	0.6799	0.4285	0.3967	0.4260	0.5461	0.2674	0.3806	0.2217
	b ₂	0.7243	0.4482	0.5600	0.3243	0.4082	0.2473	0.4049	0.1754

With a view to determining whether knowledge of common series is related to serial acquisition performance, the retarded readers were divided into the same two subgroups identified in the previous chapter, viz., Subgroup C (N = 13), consisting of subjects who made four or more errors in the enumeration of four common series (hereinafter referred to as the Series Test), and Subgroup D (N = 14), comprised of those who made less than four errors. (It will be recalled that Subgroup D originally consisted of 16 subjects but that the two eldest were excluded to equalize the mean ages of the subgroups.) The normal readers were subdivided in a similar way. The six subjects (three in Group I and three in Group II, mean CA = 9:5 at time of Series Test) who made four or more errors on the Series Test formed Subgroup C'. Had all the remaining normal readers (N = 24) been placed in the second subgroup the mean age of its members would have been considerably higher than that of Subgroup C', since the former group would have included all the subjects in Group III. Therefore, in forming Subgroup D' (N = 14, mean CA = 9:6) subjects were drawn from Groups I and II only, so that effects arising from differences in the familiarity of the series would not be confounded with those due to age differences. (The Group I normal reader whose results were not used in the computation of mean scores presented in Table 6.1 was included in the following analysis (as a member of Subgroup D'), since C, D, C', and D' may be considered to be independent groups.) Although the exclusion of Group III normal readers succeeded in balancing the mean ages of Subgroups C' and D', it also had the effect of producing a 7-month disparity between the mean ages of the normal readers (C' U D') and the retarded readers (C U D). However, as will be seen in due course, this age difference does not significantly affect the interpretation of the results.

Serial acquisition rate, as a function of word meaningfulness and trial number, and in relation to reading ability and knowledge of common series, was analyzed by means of a 2 x 2 x 4 x 2 (Reading Ability (A) x Knowledge of Series (B) x Word Meaningfulness (C) x Trial Number (D)) design, with repeated measures on factors C and D. The levels of each of the factors were as follows:

- | | |
|-----------------------------|---|
| A: a_1 = Retarded Readers | B: b_1 = Four or more errors on Series Test |
| a_2 = Normal Readers | b_2 = Less than four errors on Series Test |
| C: c_1 = High m Nouns | D: d_1 = First Trial |
| c_2 = Medium m Nouns | d_2 = Over All Trials |
| c_3 = High m' Syllables | |
| c_4 = Low m' Syllables | |

The numbers of subjects observed under each of the "treatment" combinations were as follows:

- | | |
|--------------------------|--------------------------|
| a_1b_1 : $n_{11} = 13$ | a_2b_1 : $n_{21} = 6$ |
| a_1b_2 : $n_{12} = 14$ | a_2b_2 : $n_{22} = 14$ |

In order to reduce the excessive positive skewness of the distributions of scores (items/trial) under certain of the conditions, the following transformation was applied:

$$X'_{ijklm} = \log (X_{ijklm} + 1)$$

The ABCD summary table, based on transformed scores, is shown in Table 6.2. The unequal group size made it necessary to employ a least-squares solution for the sums of squares (Winer, 1970). The computations involving within-subjects sources of variation were straightforward,

since the cell frequencies are proportional by columns. (Denoting the numbers of levels for factors A, B, C, and D by p , q , r , and s , respectively, npq is replaced by N , where $N = \sum_{ij} n_{ij} = 47$.) In the case of the between-subjects sources of variation the method due to Rao (1952) was used to compute adjusted sums of squares for the main effects and interactions ($SS_{a(adj.)}$, $SS_{b(adj.)}$, and $SS_{ab(adj.)}$).

The summary of the analysis of variance (Table 6.3) shows that the main effects for Reading Ability, Word Meaningfulness, and Trial Number were statistically significant ($p < 0.01$). More specifically, acquisition rate was an increasing function of word meaningfulness for both normal and retarded readers, but the former group achieved a higher rate than the latter on all four lists (Fig. 6.1). In general, all subjects achieved a higher "acquisition rate" on the first trial of each list than they did over the complete series of trials. (The performance of one subgroup on List R2 (Med. *m* Nouns) did not conform to the general pattern of results, as will be shown below in the analysis of the ABCD interaction.) On the other hand, there was a lack of any effect associated with subjects' knowledge of series (Fig. 6.2). Nor were there any significant two-factor interactions involving factor B, though the interaction of B with A and D approached significance ($p < 0.05$). The nature of this interaction is shown in Fig. 6.3. Within the retarded readers' group (a_1) those with a better knowledge of series (b_2) tended to achieve a higher overall acquisition rate (d_2), than those with relatively poor knowledge (b_1), even though their performance on trial one (d_1) was inferior. In the case of the normal readers (a_2) the pattern of results was reversed, in that it was the subjects with relatively poor knowledge of series (b_1) who achieved

Table 6.3 Summary of analysis of variance (four-factor experiment)

Source of Variation	SS	df	MS	VR
<u>Between subjects</u>	3.0590	46		
A	1.3942	1		
B	0.0438	1		
AB	-0.0417	1		
Subj. w. groups	1.6627	43	0.0387	
A (Adj.)	1.3505	1	1.3505	34.9260**
B (Adj.)	0.0001	1	0.0001	
AB (Adj.)	0.0020	1	0.0020	
<u>Within subjects</u>	15.4831	329		
C	6.2188	3	2.0729	83.9231**
AC	0.1519	3	0.0506	2.0486
BC	0.0706	3	0.0235	
ABC	0.1004	3	0.0335	1.3563
C x Subj. w. groups	3.1896	129	0.0247	
D	2.4431	1	2.4431	167.3356**
AD	0.1483	1	0.1483	10.1575**
BD	0.0004	1	0.0004	
ABD	0.0716	1	0.0716	4.0941
D x Subj. w. groups	0.6267	43	0.0146	
CD	0.1852	3	0.0617	4.1133**
ACD	0.1283	3	0.0428	2.8533
BCD	0.0723	3	0.0241	1.6067
ABCD	0.1392	3	0.0464	3.0933
CD x Subj. w. groups	1.9367	129	0.0150	

$$F_{0.99}(1, 43) \doteq 7.31; \quad F_{0.99}(3, 129) \doteq 3.95$$

Fig. 6.1. Profiles for factor C at levels of factors A and D (showing ACD interaction).

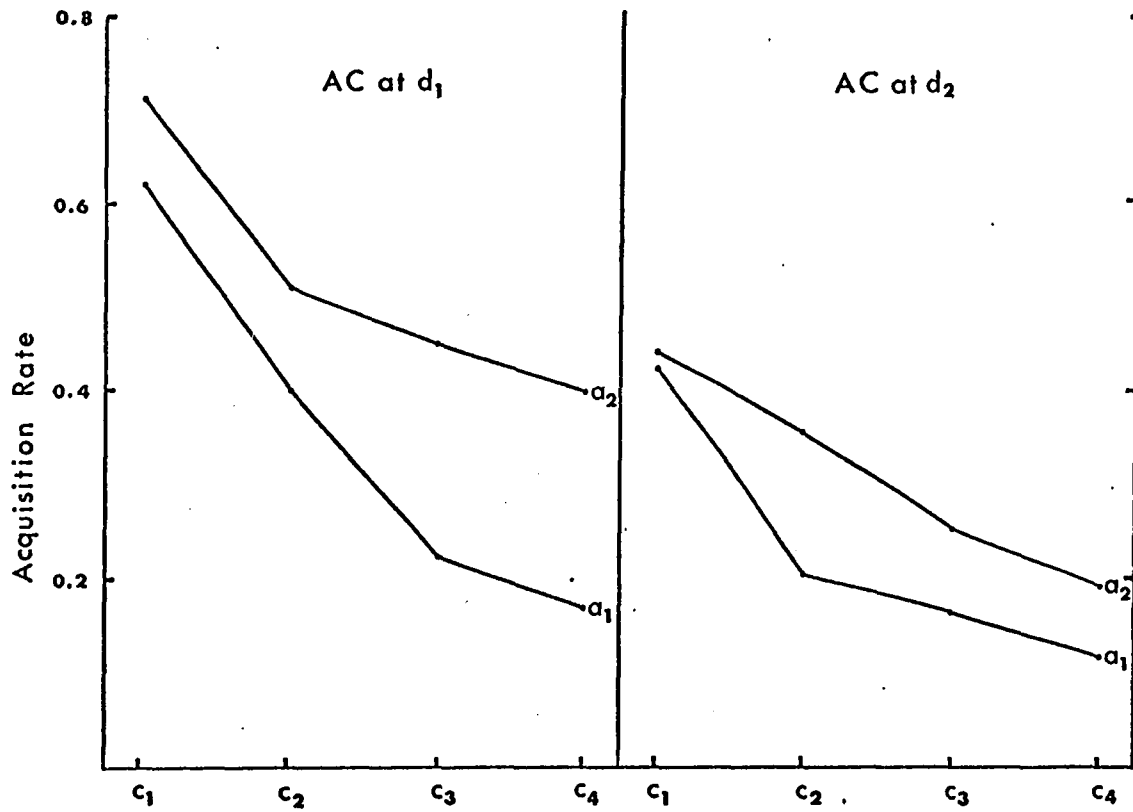
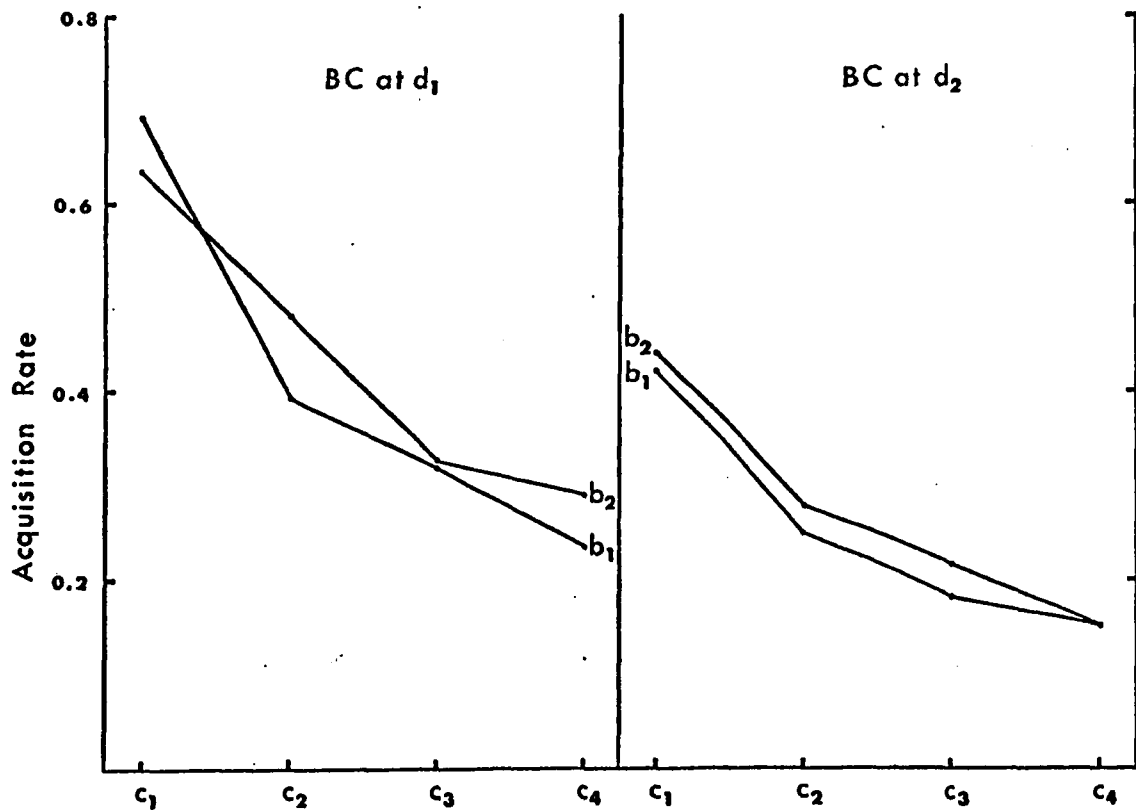


Fig. 6.2. Profiles for factor C at levels of factors B and D.



the higher overall rate (d_2), but a lower score on trial one (d_1). However, none of the simple effects of B at a_1d_m reached significance (B at a_1d_1 : $F(1, 86) = 0.61$; B at a_1d_2 : $F(1, 86) = 0.95$; B at a_2d_1 : $F(1, 86) = 0.35$; B at a_2d_2 : $F(1, 86) = 0.87$).

The only significant two-factor interactions ($p < 0.01$) were those between reading ability (A) and trial number (D), and between word meaningfulness (C) and trial number. Profiles for factor D at the two levels of factor A (Fig. 6.4) show that the difference in acquisition rate between retarded and normal readers is more pronounced on the first trial ($F(1, 86) = 46.15$, $p < 0.001$) than it is over the complete series of trials ($F(1, 86) = 11.86$, $p = 0.001$). The interaction between C and D (Fig. 6.5) appears to be due to the fact that the simple effects of trial number (for which F ratios were not calculated) are more pronounced for the lists of nouns than for lists of nonsense syllables, and furthermore, the simple effect of D is greater for High m Nouns than for Medium m Nouns.

In addition to the ABD interaction already described there was a second three-factor interaction which approached significance ($p < 0.05$), namely that between reading ability (A), word meaningfulness (C), and trial number (D). When the simple effects (Fig. 6.1) were examined it was found that as far as performance on the first trial (d_1) was concerned, there was a significant difference ($p < 0.01$) between the retarded and normal readers' scores in the case of the two nonsense syllable lists (A at c_3d_1 : $F(1, 344) = 26.40$; A at c_4d_1 : $F(1, 344) = 27.31$), but not for the two real word lists, though the latter effects did approach significance (A at c_1d_1 : $F(1, 344) = 4.46$, $p < 0.05$; A at c_2d_1 : $F(1, 344) = 6.71$, $p = 0.01$). Regarding the overall rates of

Fig. 6.3. Profiles for D at levels of A and B (showing ABD interaction).

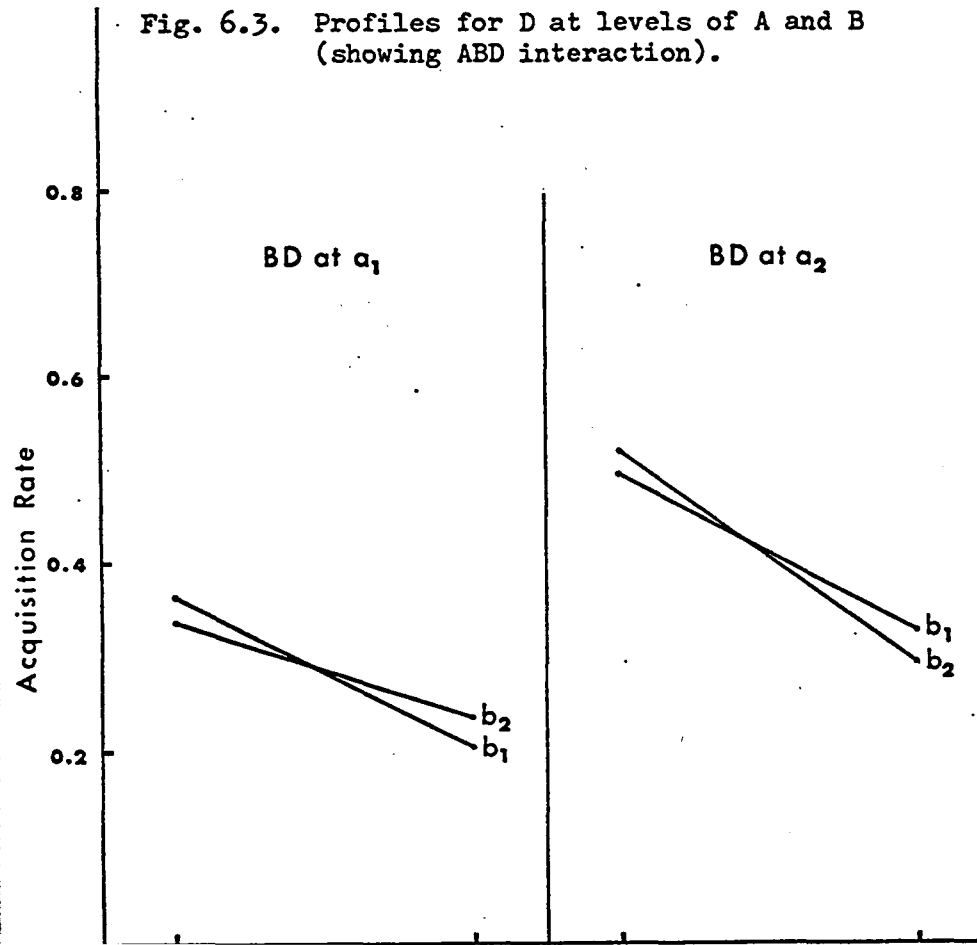


Fig. 6.4. Profiles for D at levels of A.

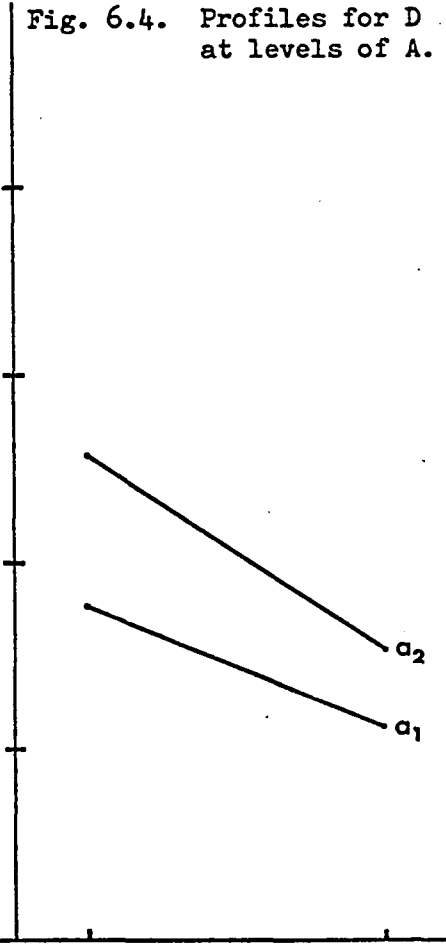
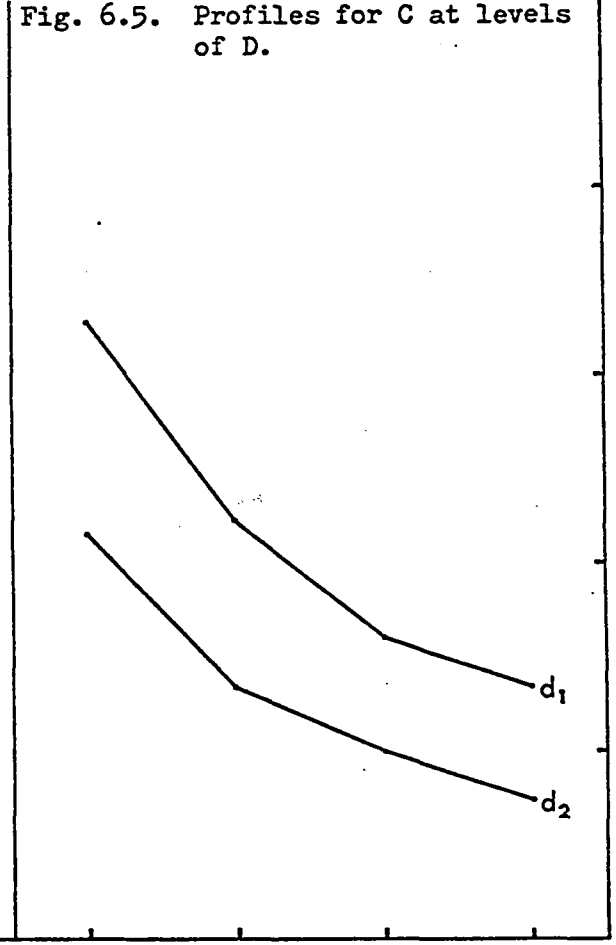


Fig. 6.5. Profiles for C at levels of D.



acquisition (d_2), there was a significant difference between the two groups scores for the list of Medium m Nouns (A at c_2d_2 : $F(1, 344) = 12.15$, $p < 0.01$), but virtual equivalence between their scores on the High m list (A at c_1d_2 : $F(1, 344) = 0.16$). In contrast to the situation obtaining on the first trial of the nonsense syllable lists the overall acquisition rates for these lists did not differ significantly from one group to the other, though the effect for the High m list approached significance (A at c_3d_2 : $F(1, 344) = 4.38$, $p < 0.05$; A at c_4d_2 : $F(1, 344) = 2.81$, NS).

It remains to examine the nature of the ABCD interaction, which also approached significance ($p < 0.05$). It is evident from Fig. 6.6 that, in the case of the retarded reader subgroups (a_1b_1 and a_1b_2) and the normal reader subgroup with better knowledge of series (a_2b_2), the number of items acquired on the first trial is higher than the overall acquisition rate, for each of the four lists, though the difference does not reach a significant level in every case:

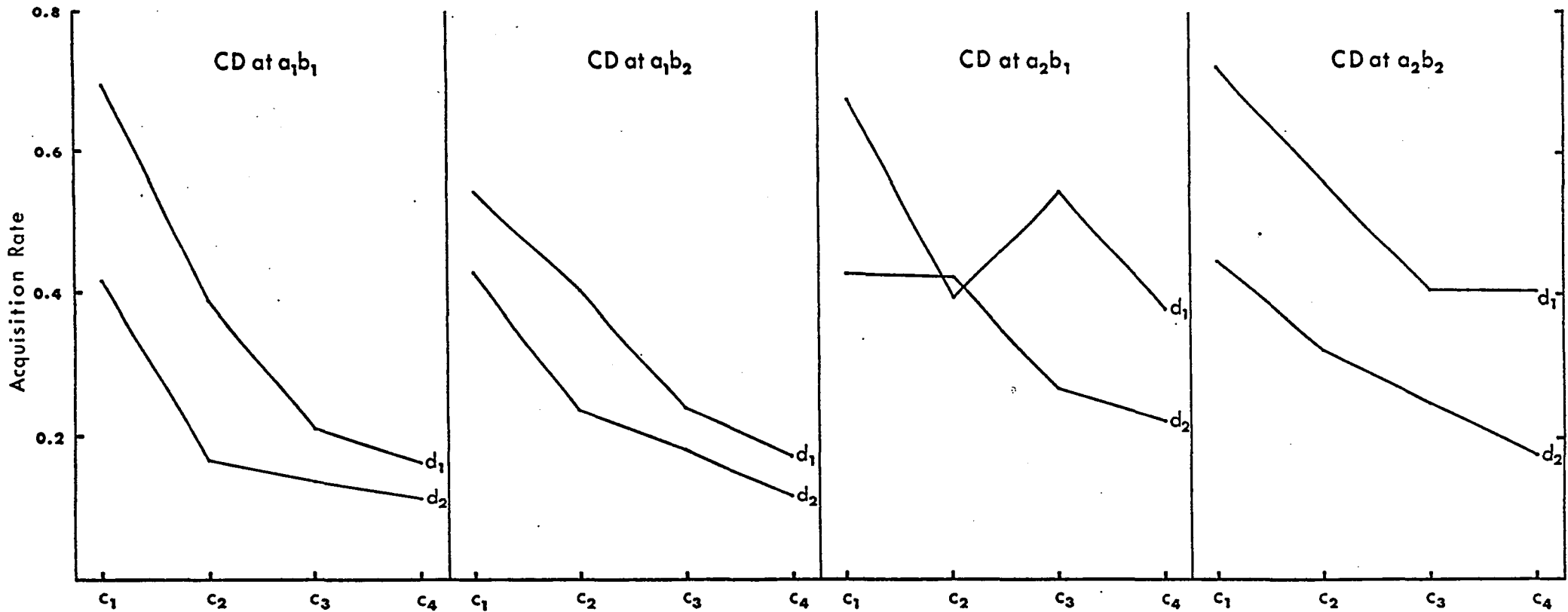
Retarded Readers (Subgroup a_1b_1):

- D at c_1 : $F(1, 172) = 33.45$, $p < 0.01$;
- D at c_2 : $F(1, 172) = 21.56$, $p < 0.01$;
- D at c_3 : $F(1, 172) = 2.25$, NS;
- D at c_4 : $F(1, 172) = 1.16$, NS.

Retarded Readers (Subgroup a_1b_2):

- D at c_1 : $F(1, 172) = 6.55$, $p < 0.05$;
- D at c_2 : $F(1, 172) = 13.53$, $p < 0.01$;
- D at c_3 : $F(1, 172) = 1.53$, NS;
- D at c_4 : $F(1, 172) = 1.52$, NS.

Fig. 6.6. Profiles for factor C at levels of factors A, B, and D (showing ABCD interaction).



Normal Readers (Subgroup a_2b_2):

D at c_1 : $F(1, 172) = 35.82, p < 0.01$;

D at c_2 : $F(1, 172) = 26.09, p < 0.01$;

D at c_3 : $F(1, 172) = 12.17, p < 0.01$;

D at c_4 : $F(1, 172) = 24.75, p < 0.01$.

An interesting departure from this pattern of results occurs in the case of the normal readers with poor knowledge of series who appear to experience a disproportionate degree of difficulty in retaining Medium m Nouns on the first trial, but who recover sufficiently over the remaining trials to raise their average acquisition rate slightly above the number retained on the first trial:

Normal Readers (Subgroup a_2b_1):

D at c_1 : $F(1, 172) = 12.72, p < 0.01$;

D at c_2 : $F(1, 172) = 0.17, NS$;

D at c_3 : $F(1, 172) = 15.63, p < 0.01$;

D at c_4 : $F(1, 172) = 5.08, p < 0.05$.

An alternative way of analysing the normal readers' results is to compare, for each of the four lists, the mean numbers of items retained on the first trial by the two subgroups. In fact, their scores were similar, except in the case of the list of Medium m Nouns, where the difference between the number of items retained on the first trial by the retarded readers with poor knowledge of series (a_2b_1) and the number retained by those with better knowledge (a_2b_2) approached significance (B at $a_2c_1d_1$: $F(1, 344) = 0.38, NS$; B at $a_2c_2d_1$: $F(1, 344) = 5.19, p < 0.05$; B at $a_2c_3d_1$: $F(1, 344) = 3.70, NS$; B at $a_2c_4d_1$: $F(1, 344) = 0.16, NS$). In view of the relatively small size of subgroup a_2b_1 , it cannot be assumed with complete confidence that the above tests provide a satisfactory estimate of the effects of D at $a_2b_1c_k$ or of B at $a_2c_kd_1$, and the findings would need to be confirmed in a larger sample before undertaking further investigations.

6.3 Auditory short-term memory, in relation to reading ability and knowledge of common series.

In view of the earlier finding that members of Subgroup C (a_1b_1) have inferior short-term memory when compared with members of Subgroup D (a_1b_2), the absence of both a main effect for B and a simple effect for B at a_1d_1 is somewhat unexpected. Although there are considerable differences between the Digit Span test and the serial acquisition task it seems reasonable to suppose that performance on trial one of the latter task would bear some relationship to the capacity of short-term memory (as denoted by the subject's Digit Span score). One aspect of the Digit Span test which makes a direct comparison difficult is that it is composed of two parts: digits forward and digits backward. It was thought desirable, therefore, to ascertain the extent to which the previously observed difference between Subgroups C and D arise from performance on the digits forward test alone. To this end, the transformation used in the previous analysis, viz., $X' = \log(X + 1)$, was first applied to subjects' raw scores on digits forward. A 2×2 (Reading Ability (A) \times Knowledge of Series (B)) analysis of variance was then carried out using the transformed score as the criterion variable. The levels of factors A and B and the subgroups of normal and retarded readers under the different combinations of these levels were the same as in the previous analysis. As the cell frequencies were again unequal, it was necessary to use Rao's least-squares solution for the sums of squares, the results of which are shown in Table 6.4, together with the AB cell means. It would appear that the previously reported difference in Digit Span scale score between Subgroups C (a_1b_1) and D (a_1b_2) is, to a significant extent, the result

Table 6.4 Two-factor (Reading Ability (A) x Knowledge of Series (B)) experiment with digit span (forward) transformed raw score as criterion variable.

(i) Cell Means:

	b_1	b_2
a_1	0.7468	0.8101
a_2	0.7650	0.8271

(ii) Cell Frequencies:

	b_1	b_2	
a_1	13	14	27
a_2	6	14	20
	19	28	47

(iii) Summary of analysis of variance

Source of Variation	SS	df	MS	VR
A (Adj.)	0.0034	1	0.0034	1.1724
B (Adj.)	0.0433	1	0.0433	14.9310**
AB (Adj.)	0.0000	1	0.0000	
Within cell (Error)	0.1262	43	0.0029	

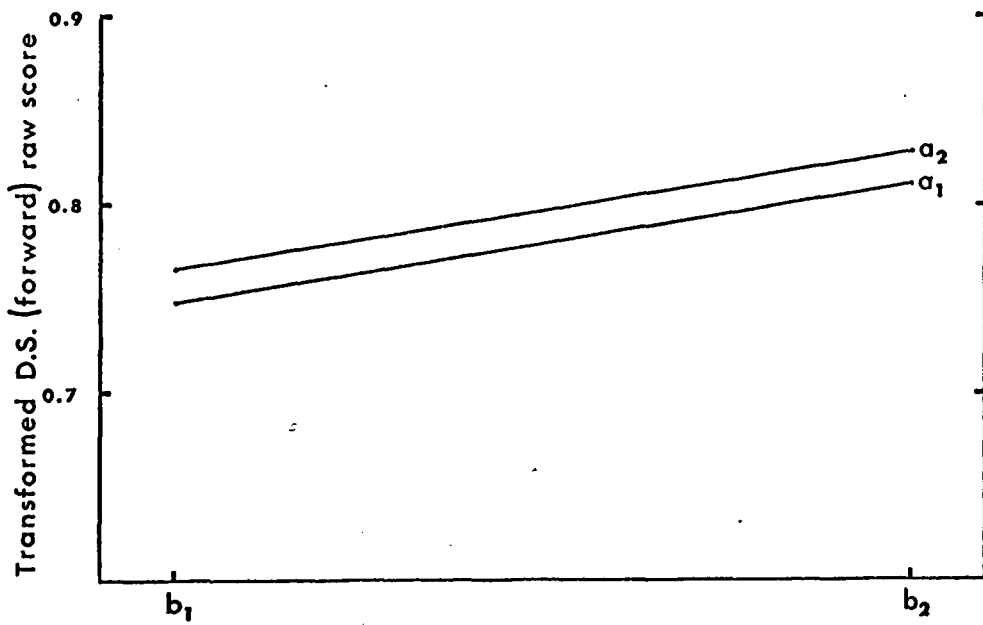
$$F_{0.99}(1, 43) \doteq 7.31$$

of a difference in performance on digits forward. Moreover, the association between factor B and digit span (forward) is equally strong for the normal readers (Fig. 6.7). On the other hand subjects' level of reading ability (A) did not bear a significant relationship to digit span (forward), so that the overall pattern of results is just the reverse of that obtained when the criterion variable was acquisition rate on the serial learning task. However, it should be borne in mind that the composition of subgroups under the different levels of A and B was such that the normal readers (a_2) were, on average, about 7 months younger than the retarded readers (a_1) at the time that the Digit Span test was given, and consequently the effect of factor A was probably less marked than it would have been had the two groups been matched for age. In order to ascertain how far this imbalance between the mean ages of the two groups affected the result, the transformed digit span (forward) raw scores for the complete sample of normal readers ($N = 30$, mean CA = 9:10) were compared with those of the retarded readers ($N = 30$, mean CA = 9:8) by means of the t test with paired observations, but the difference between the two groups' mean scores still fell short of the significance level ($p = 0.01$) used to evaluate the effect of factor B ($t = 2.40$ (equivalent to an F ratio of 5.76), $df = 29$, $0.01 < p < 0.05$).

6.4 Discussion

It is clear from the results of the first experiment that retarded readers' knowledge of common series is unrelated to their performance on a serial learning task, irrespective of whether the list contains words or nonsense syllables, and this finding also applies to normal

Fig. 6.7. Profiles for factor B at levels of factor A
(criterion variable = digit span (forward)
transformed raw score).



readers under all but one of the conditions investigated. The exception occurred in the case of the list of Medium m Nouns, where subjects with poor knowledge of series experienced a disproportionate degree of difficulty in retaining items on the first trial.

The results obtained for the retarded readers are somewhat difficult to reconcile with the findings of Chapter 5, where it was shown that those with a better knowledge of series tend to achieve a superior Digit Span score, and the latter finding was therefore examined more closely to ascertain the extent to which a difference in the forward span had contributed to the overall result. In fact, a difference was found between the mean scores of the two groups, even when the comparison was based on the forward span alone. Moreover, amongst normal readers, knowledge of common series seems to depend on immediate memory span to much the same extent as in retarded readers. As mentioned above, there appears to be an association, amongst normal readers, between knowledge of series and the number of Medium m Nouns retained on the first trial, but why the difference in digit span score between one subgroup and the other should not be more widely reflected in differences in performance on the serial learning task is not immediately apparent.

In contrast to the above findings pertaining to knowledge of common series, the retarded readers as a whole found the serial learning task much more difficult than the normal readers, the difference in performance being more apparent on the first trial than when measured over the complete series of trials. Though the immediate memory span of retarded readers is also shorter than that of the normal

readers, the association is noticeably weaker than that between serial acquisition rate and reading ability. In fact, as intimated above, immediate memory span appears to be more effective in determining knowledge of series, irrespective of level of reading ability.

The rate at which items were acquired on the serial learning task was an increasing function of word meaningfulness, the effect of variations in this parameter being, on the whole, the same for both retarded and normal readers. However, while the interaction between reading ability and word meaningfulness failed to reach significance, the relative magnitude of inter-group differences at different levels of word meaningfulness varied according to whether the index of performance was the overall acquisition rate or the number of items acquired on the first trial. Thus, whereas the normal readers retained, on average, 2.8 times as many nonsense syllables (High m' and Low m') on the first trial, compared with the retarded readers, their overall acquisition rate for the same type of item was only 1.8 times as great. This pattern was reversed in the case of Medium m Nouns where the number of items acquired on the first trial by the normal readers was 1.5 times that of the retarded readers, but the overall acquisition rate was 2.1 times as great. The condition under which the retarded readers achieved a level of performance closest to that of the normal readers was the one involving High m Nouns, but then only in respect of the overall acquisition rates, and not the numbers of items recalled on the first trial. Nevertheless, this finding suggests that the power of long-term retention in retarded readers may be impaired only in relation to material which is either difficult to visualize, or evokes few verbal associations. The absence of a significant interaction

between word meaningfulness and reading ability in respect of the overall rate of acquisition of nonsense syllables (where the effects of changes in I are thought to be minimal) suggests that the retarded readers are no more sensitive than the normal readers to variations in m, and therefore that their improved performance on the list of High m Nouns is facilitated primarily by the greater availability of images for this type of item. It is doubtful, therefore, whether the differences in acquisition rate between the two groups on the remaining conditions can be explained either by the relative availability of images or the ease with which verbal associations are formed.

Chapter 7

7.1 The judgment of spatial orientation

A number of findings arising out of the work of the preceding chapters are considered here at greater length in order to determine how far they are consistent with the theoretical model which formed the basis for this study. The aim, in developing this model, was to show that the presence of certain developmental anomalies in children who are retarded in reading might be due to the failure of the visual system to establish or maintain an intrinsic frame of reference. It was proposed that one of the main functions of the frame is to enable judgments to be made of a figure's egocentric orientation, and that if its acquisition were impeded, letter orientation errors in reading and writing might persist at an age when they have normally been overcome. This hypothesis is to some extent supported by the finding that there is an association between the stage reached by the child in the comprehension of left-right and above-below (but not further-nearer) relations and the occurrence of letter orientation errors in writing. Although there was also evidence of an association with the level of euclidean development, it was not so well-defined and, moreover, could be interpreted as being due not to the inferior performance of Subgroup A (orientation errors present), but to the superior performance of Subgroup B (orientation errors absent), insofar as the former reached the same level as the normal readers on all seven axes-of-reference tests, while the latter were in advance of the normal readers on two of them.

Although the findings summarised above accord with the theoretical predictions, the methods used to test these predictions are open to two basic criticisms. The first concerns the water level and plumb-line tasks used to assess the child's conceptions of the horizontal and vertical. These axes constitute a frame of reference which is fixed in physical space, whereas it is thought that the frame which facilitates judgments of a figure's egocentric orientation is one based on the principal axes of the head. Now, it was argued that once the child reaches the final stage in the development of operational thought, his representation of physical space would allow him to make judgments about the orientation of figures in egocentric space. However, if an egocentric frame is established independently through quite different processes at an earlier age, it is doubtful whether Piaget and Inhelder's axes of reference tests would provide a valid index of its state of development. In fact, data bearing more directly on this issue were obtained through a supplementary experiment, not reported earlier, which showed that retarded and normal readers alike are able to judge the egocentric orientation of a line with a high degree of accuracy (see Appendix E).

Thus, whether or not they produce orientation errors, retarded readers appear to be at least as advanced as normal readers in the acquisition of euclidean concepts, and this finding applies irrespective of whether the reference system is based on the axes of physical space or defined by the principal axes of the observer's head. As pointed out in Chapter 1, it is the projective, rather than euclidean properties of spatially confusable letters (b, d, p, q; n, u; m, w) which serve to distinguish one from the other, so

that the state of development of euclidean concepts may be of no relevance as far as their identification is concerned. The fact that the retarded readers who were free of orientation errors were more advanced than those who produced them on three of the axes of reference tests would, on this view, be seen as an incidental concomitant of the mutual interdependence of euclidean and projective concepts, rather than an association which has any bearing, in functional terms, on the presence or absence of orientation errors. Notwithstanding this difference between Subgroups A and B, the results for the complete group fail to bear out Lovell, Shapton and Warren's (1964) conclusion that normal readers are at a more advanced stage than retarded readers in the acquisition of euclidean concepts. It was suggested in Chapter 3 that Lovell et al. could have obtained this result through a failure to adequately control for intelligence, but it is doubtful whether this factor had a significant effect in view of the later finding (see Table 5.9) that two groups (namely Subgroups C and D) who show significant differences in both Verbal and Performance IQ may nevertheless be at comparable stages in the acquisition of euclidean concepts.

In the case of the three projective relations, the situation is somewhat more complicated in that two of them - left-right and further-nearer - are based on the egocentric system, whereas the third - above-below - is generally defined in relation to physical space, although in certain circumstances where the longitudinal axis of the observer is displaced from the vertical the terms above and below could be used in relation to the former axis. In fact, irrespective of the individual's attitude in space it is precisely the egocentric top-bottom which, in conjunction with the other

components of the frame, is brought into play in various operations which form part of the reading process, from the initial actions involved in opening a book and orienting the page, to scanning the lines of text and identifying letters related through spatial transformation(s). Thus, unlike Piaget and Inhelder's axes of reference tests, the measures used to assess comprehension of left-right and further-nearer relations do bear upon the hypothesis under test, insofar as they pertain to the egocentric frame rather than a contextual reference provided by the physical environment. On the other hand, when the subject makes above-below judgments, he has a choice, in theory, of referring the positions of the objects to either an egocentric frame or one based on physical space, though it is thought that the latter would be the natural reference to use in the task employed here.

There are further problems of interpretation concerning the projective tests. In describing the criteria used to score these tests, it was pointed out that on each of the problems which serve to define the developmental stages, various patterns of error may be seen in children who are at intermediate stages. Some of these patterns of error are of such regularity and coherence that it can fairly safely be concluded that the child has an inadequate grasp of the concept, and is adopting a strategy based on a more primitive level of understanding. However, in other cases, where the patterns of error are less predictable, the reasons for their occurrence are less obvious, but one explanation which cannot be discounted is that the associations between the conceptual relations and the terms used to express them have not been firmly established. For example, where the error pattern

is of the type described as Partial Success (see Table 3.5), in which a single error is incurred in a series of four questions, it could be argued that a breakdown in the labelling process is more likely to have been responsible than a flaw in the conceptual schema. However, without further evidence one cannot be certain about the correct interpretation, except as already mentioned in the case of error patterns which exhibit a high degree of regularity, where a deficit in the labelling process can probably be ruled out. It might have been more appropriate, therefore, to have assessed children's projective concepts in a way which does not require comprehension or production of the corresponding terms, as Piaget and Inhelder did in an experiment in which subjects reproduced or drew the arrangement of objects in a model village. There is clearly a need to distinguish between the conceptual and verbal aspects of this type of task, in view of Asso and Wyke's (1970) finding that, in children between the ages of 4½ and 7½, the ability to discriminate between figures composed of line elements and circles in various spatial relationships (over, under, beside, between, left, right, and centre) is virtually uncorrelated with comprehension of the corresponding terms, as assessed by their success in picking out the same figures in response to verbal instructions (e.g. Show me where the ball is over the line).

If the development of projective concepts were to be assessed by means of a non-verbal method, it would be important to ensure that the relative positions of the objects concerned are actually being judged in projective terms, by presenting them in such a way that the subject cannot make use of framework cues which may be present either in the materials themselves or in the immediate surroundings of the

test situation. In discussing Bryant's (1974) experiment on the discrimination of spatial position it was pointed out that his method would not have prevented the use of framework cues, and the same criticism could be made of Asso and Wyke's simultaneous matching to sample procedure. In the present study, where a verbal method was used, successful performance on the tests pertaining to at least two of the relations (left-right and further-nearer) would have depended on correct use of the projective system, even though a contextual framework might also have been brought into play for certain purposes. In fact, it was evident from remarks made by some subjects following Test 4b of the left-right and further-nearer series (3 hidden blocks) that they encoded the positions of the blocks in terms of their proximity to various features of the room. Of course, in order to answer the questions which followed it would have been necessary to re-conceptualise the positions in projective terms. Nevertheless, none of the research carried out so far has yielded data on the conceptual basis of the projective frame which are undistorted by individual differences in labelling skills or in the use of framework cues. A design which does not suffer from these methodological weaknesses would incorporate the following features: (1) a successive discrimination task, thereby ensuring that the sample figure itself cannot serve as a contextual frame and (2) a field of view which contains no visual features other than those elements whose spatial relationship is being judged. Some pilot work along these lines was conducted with the apparatus described in Appendix E, but the reliability of the data was low on account of a defect in the mechanism which resulted in a number of false positive responses. In any event,

error rates were not high enough to permit comparisons to be made, though it is believed that the method would be worth developing for use with younger children. Once such a method had been perfected, it would be of interest to compare the discrimination of spatial relationships with comprehension of the corresponding terms, as Asso and Wyke did, and to extend their findings by relating performance on both these tasks to the incidence of letter orientation errors. Assuming that the use of a successive, rather than a simultaneous discrimination task leads to the same conclusion as that reached by Asso and Wyke, namely that the ability to visually discriminate spatial relations is uncorrelated with comprehension of the corresponding terms, then it seems reasonable to suppose that the ability to identify spatially confusable letters would be more highly correlated with one of these skills than with the other. If so, it would help to resolve the question of whether letter orientation errors arise from a deficiency in the conceptual schema, or whether they are due to lack of verbal proficiency.

When it comes to analysing what functional relationship, if any, exists between the level of projective development and the occurrence of letter orientation errors, it is necessary to take into consideration the criteria adopted in scoring the tests, as these play a crucial role in determining the developmental stage to which the subject is assigned. Although the requirement of perfect performance on a prescribed number of trials is undoubtedly a safeguard against chance successes determining the outcome, there is a possibility that attentional factors might play a disproportionate role in defining the level at which the child is placed. For example, a momentary lapse of

attention on the part of a child who actually possesses a fully-developed concept of left-right may lead to a simple error on Test 4b (three hidden blocks), with the result that he is assigned to the preceding stage of development. Presumably a slight impairment in concentration could also lead to an increased incidence of letter orientation errors, so that although the latter would on the face of it be related to the level of projective development in the manner predicted, the theoretical explanation for the association might be quite different from the one postulated. On the other hand, what may appear to be a greater degree of distractibility in retarded readers could be a reflection of the fact that they have not achieved complete automaticity in the encoding and rehearsal of information, with the result that the demands on attentional processes are that much greater and therefore more liable to disruption. However, the finding that retarded and normal readers are at comparable stages of development in their understanding of the further-nearer relation tends to throw some doubt on both the above explanations, and it is therefore necessary to examine more closely the implication that there is a real functional relationship between the level of development of fronto-parallel (i.e., left-right and above-below) relations and the occurrence of letter orientation errors.

It will be recalled from the analysis in Chapter 1 that the disappearance of orientation errors from the reading and writing of the great majority of children at the age of 7 or 8 appears to coincide with two specific developments in the evolution of spatial thought. The first, identified by Piaget and Inhelder, is the ability consistently to take account of left-right and before-behind relation-

ships in drawing or physically reconstructing the layout of a group of objects. In keeping with this finding, Bryant (1974) reported that an absolute code for position is acquired at about the same time though, as already pointed out, in neither of the studies were adequate precautions taken against the use of framework cues. The second development which occurs at about this age is that the child acquires the capacity to make successive discriminations of the egocentric orientation of a line (Rudel and Tueber, 1963). If these two advances provide the conceptual basis for his ability to distinguish letters which are related through spatial transformation(s), it is then pertinent to enquire what relationship they bear to the stages of projective development described in Chapter 3. From a logical point of view, it seems reasonable to suppose that the child would be capable of distinguishing between left-right, or up-down, mirror image forms once he had learnt to judge the relative position of two external objects, since identification of the letter b, for example, could be reduced to an analysis of the relative positions of its constituent features - the straight and the curve. Now, it will be recalled from Chapter 3 that, in investigating children's comprehension of left-right relations, a stage corresponding to successful performance on the two-object problem was not included in the developmental scale, primarily because Laurendeau and Pinard do not consider it an essential phase in the evolution of the concept. Nevertheless, a two-block problem was included in the left-right test series, even though the results do not form part of the analysis by stages. In fact, this problem was included in Piaget's (1924) original study, in which it was found that at least 75% of 7-year-olds are capable of making correct

judgments. In a replication of Piaget's study, Elkind (1961) found that children reached this stage at the slightly later age of 8 years. In any event, this stage appears to coincide with the two described above, and in particular it is worth noting that the age at which the child first understands the terms left and right when applied to two external objects is not appreciably later than the age at which he is able to take account of these relationships in a non-verbal task involving the spatial arrangement of a group of objects, though in making this comparison it should be borne in mind that the latter task, in the form devised by Piaget and Inhelder (1956), was conceptually more complex than the former.

The above findings are consistent with the hypothesis that a functional relationship exists between the stage reached in the conceptualization of left and right and the perception of figure orientation, and furthermore that this relationship is established by the age of 7 or 8, when orientation errors have normally been overcome. Yet, if the comprehension of left and right in the sample under study is defined in accordance with the same scale used for the concepts of above-below and further-nearer (i.e., including Stage IC, instead of II, so as to take account of performance on the two-block arrangement), then it is found that in Subgroup A of the retarded readers the numbers of subjects at Stages O-IB, IC, and III are 4, 8, and 1, respectively. In other words, all but four have reached a stage which, in the light of the considerations outlined above, should be sufficiently advanced to support judgments of figure orientation.¹

¹ By comparison with the results obtained when subjects were assigned to Stages O-IB, II, and III (Table 3.12), members of Subgroup B did not show the same degree of superiority relative to A, the numbers at each Stage being as follows: Stage O-IB: 5; Stage IC: 5; Stage III: 4; (Uncl: 1). The apparent increase in the number at Stage O-IB is accounted for by 5 subjects who were actually at Stage II, or in one case III, but failing the two-block arrangement, were assigned to O-IB in accordance with the procedure used to place subjects on the above-below and further-nearer scales.

The reason for this apparent anomaly was explored by examining the distribution of subjects on the left-right scale (defined in terms of Stages O-1B, II, and III). It was found that the differences between Subgroups A and B are largely due to the fact that there are five members of A at Stage O-1B, compared with a single subject from B, and no member of A at Stage III, compared with five from B. Orientation errors incurred by the five members of Subgroup A who are at Stage O-1B might reasonably be supposed to result from an inadequate conception of left and right, but the same explanation is unlikely to hold true for the seven subjects at Stage II, all of whom were also successful in performing the two-block task. Nevertheless, the fact that there are no Subgroup A subjects at Stage III suggests that processes brought into play in the solution of the three-block problem may also be involved in the identification of letters which are related through spatial transformation(s). One feature of the three-block problem which may be relevant is that in Test 4b (three hidden blocks) the subject was required to memorize the spatial position of the blocks. In fact, Piaget (1924) found that subjects did not achieve success on the problem involving three hidden blocks until the age of twelve, or about a year after they are able to identify the relative positions of three visible blocks. However, Laurendeau and Pinard (1970) were unable to confirm the presence of this decalage, their results (based on the performance of 144 subjects between the ages of 5 and 12) indicating that the age of accession is the same (9:9) whether the task involves visible or hidden blocks. They attempted to justify this finding from a theoretical standpoint by arguing that the act of reconstructing the spatial relationships involves nothing beyond what is entailed in their comprehension,

provided that the number of objects does not "surpass the subject's capacities for simultaneous apprehension" (p. 274). Even so, in this instance, where there is reason to suspect that some subjects suffer from deficits in learning and memory, it might be a mistake to assume that Tests 4a and 4b are of the same order of difficulty, particularly as there is evidence to suggest that retarded readers are less likely to engage in verbal rehearsal when performing short-term memory tasks (Kastner and Rickards, 1974; Tarver, Hallahan, Kauffman, and Ball, 1976; Torgesen, 1977; Torgesen and Goldman, 1977). To ascertain whether a factor of this sort played a part in the outcome, the retarded readers' scores on Tests 4a and 4b were examined separately. Considering first of all the results obtained by Subgroup A, four subjects gave correct answers to all eight questions of Test 4a, compared with three subjects on 4b. In Subgroup B, nine subjects achieved an error-free performance on Test 4a, while seven did so on Test 4b. These results are broadly in agreement with Laurendeau and Pinard's findings and tend to rule out the possibility that members of Subgroup A fail to reach Stage III on account of the disproportionate degree of difficulty presented by Test 4b. The implication that verbal rehearsal strategies are as efficient as in Subgroup B is to some extent supported by the finding that these Subgroups perform equally well on a test of auditory short-term memory (Digit Span). If, as the foregoing analysis suggests, Subgroup A are showing a genuine delay relative to B, in acquiring the left-right concept, it remains to explain why the majority are at a stage which, in the light of the earlier theoretical argument, should be advanced enough to subserve the identification of letters which are related through spatial

transformation(s). Of course, the argument that the perception of orientation depends on the ability to make explicit judgments of the relative position of a figure's constituent features is not in complete accord with the hypothesis put forward in Chapter 1, where it was proposed that the orientation of a figure is judged in terms of changes in its phenomenal form.¹ However, the experimental findings of Chapter 4 failed to support the second hypothesis, while there was a measure of support for the first in the results of the projective tests. Before giving further consideration to inadequacies in the first hypothesis, the implications of the findings of Chapter 4 for the second hypothesis will be considered in more detail.

To recapitulate the argument put forward in Chapter 1, it was suggested that the cumulative effects of visual experience give rise to a composite *memory trace* which is asymmetrical about the vertical and horizontal axes. This trace complex exerts a covert influence on the appearance of the visual field or any object within it, with the result that a figure which is asymmetrical about one or both of its principal axes undergoes changes in phenomenal form when rotated or reflected within a fronto-parallel plane. The different phenomenal forms which a figure presents in different orientations enables it to be distinguished from its left-right or up-down mirror image. However, the results of the experiments described in Chapter 4 showed that when a figure, such as a word or face, is inverted the extent of the change

¹ The two hypotheses are not necessarily mutually exclusive, in the sense that both types of process could rely on the same structure. Indeed, if they are not compatible with each other, it is debatable whether the projective measures, which require the subject to make explicit judgments of spatial position, can be considered appropriate tests of the hypothesis under investigation.

in phenomenal form is no greater in normal than in retarded readers, and, within the latter group, is no greater in those who are free of orientation errors than in those who produce them. Even so, it may be premature to abandon the idea that the perception of orientation is based on a mechanism of this sort, since alternative hypotheses have yet to be fully evaluated. It is conceivable that both retarded and normal readers rely on changes in the phenomenal form of a figure in order to recognize its orientation but that the source of errors in orientation lies elsewhere in the process. This argument is to some extent supported by the observation that it is letters whose transformed variants are also members of the alphabet which are the main source of confusion. Although no firm evidence available, it is the writer's impression that reversals of the other letters (and numbers), and also mirror reading and writing involving complete words, are more likely to be found in younger children (between 4 and 6 years), irrespective of their aptitude for reading and writing. Such phenomena cannot be explained by a weakness in visual-verbal learning since verbal labels for the reversed or inverted forms do not exist.

The hypothesis that reversals of letters such as b, d, p, and q occur on account of the dissolution of phoneme-grapheme correspondences is to a certain extent supported by studies which have shown that retarded readers suffer from a deficiency in verbal labelling (Denckla and Rudel, 1976a, b; Eakin and Douglas, 1971; Spring, 1976; Spring and Capps, 1974). These authors found that, on a rapid automatic naming task, retarded readers are both slower and less accurate than normal readers in generating the names of familiar objects, colours, letters and numbers. Although there is no direct evidence to suggest

that performance on these naming tasks is related to the ability to define the meanings of words, it is worth noting that the vocabulary level of Subgroup A was inferior to that of B (see Table 3.10), and that this disparity was too large to be accounted for by the difference in reading ages. Even so, it is doubtful whether Subgroup A should be considered to be deficient in this respect, since the normal readers to whom they were matched were supposedly of the same level of verbal ability. On the other hand, it will be recalled from Chapter 5 (Table 5.8) that the tolerance (+/-1) on the Maxwell Verbal Score (MVS) was not close enough to ensure that the mean vocabulary level of Subgroup C did not differ significantly from that of its control. Carrying out a similar analysis for Subgroups A and B and their respective controls, it was found that the difference between A's mean score (11.3) and that of its control (12.0) approached significance (t (paired obs.) = -1.56, $df = 12$, $0.05 < p < 0.1$ (1-tail)), while B obtained a score (13.2) much closer to that of its control (13.1), ($t = 0.25$, $df = 14$, NS). Given that it was the intention to match Subgroup A and its control for MVS, the above difference is perhaps of greater consequence than the results of the statistical tests indicate. Moreover, when it is considered how infrequent orientation errors are, it is likely that any related deficiency in verbal processes would be subtle, and therefore not surprising if its effect on vocabulary per se were as insignificant as the above figures suggest. In the circumstances, it may be more instructive to measure the subject's vocabulary level against some other aspect of his own performance. To this end, a baseline was established by computing, for each subject, the mean of the nine WISC subtest scores. The extent

to which his Vocabulary score deviated from this mean was then determined, deviations above the mean being counted as positive and those below the mean as negative. For Subgroup A ($N = 13$), the mean deviation score was -0.21 , a figure which was not significantly different from that obtained by the respective Verbal controls ($+0.33$), (t (paired obs.) = -0.86 , $df = 12$). Similarly, Subgroup B ($N = 15$) obtained a mean deviation score of $+1.07$, and its control group a score of $+0.44$, the difference again being non-significant ($t = 1.52$, $df = 14$). The negative deviation exhibited by Subgroup A would, of course, have been more pronounced but for the fact that some retarded readers also exhibit deficiencies, relative to their controls, in Arithmetic and Digit Span, the effect being that their mean of subtest scores is correspondingly reduced. To ascertain by what amount the Vocabulary deviation is thereby attenuated, the above calculations were repeated with Arithmetic and Digit Span scores excluded from the computation of the mean. It was found that the mean deviation score of Subgroup A increased (in absolute terms) to -0.88 , though it still did not differ significantly from the score ($+0.04$) obtained by the Verbal controls (t (paired obs.) = -1.44 , $df = 12$). The corresponding figures for Subgroup B and its control were $+0.30$ and $+0.10$, respectively, the difference also being non-significant ($t = 0.47$, $df = 14$), though in the direction opposite to that obtaining between A and its control. Though failing to confirm the verbal deficit hypothesis in a convincing manner, the above pattern of results is nevertheless suggestive and raises the question of whether an impairment in the visual-verbal associative process could also affect performance on the tests used to assess comprehension of left-right

and above-below relations. In order to try and answer this question a probabilistic approach will be adopted. It will be shown that the apparent delay in the acquisition of left-right and above-below relations in Subgroup A may be a consequence of an unstable association between the verbal label and its referent, and that the frequency with which the association is disrupted is of the same order as the frequency of occurrence of letter orientation errors.

For the purposes of the analysis which follows it will be convenient to consider the results of one of the two tests used to assess whether the child had attained what Piaget terms a completely objectified concept of left and right, namely that which called for judgments to be made of the relative position of three visible blocks (Test 4a). It will be recalled that the child's score on this test was based on his responses to four arrangements of blocks, the first two involving four questions about end blocks and the second two four questions about middle blocks. In analyzing the origin and pattern of errors produced on this test a number of simplifying assumptions will be made, the first being that there are three categories of error: those produced by the dissociation of verbal label and concept, those which are a function of the level of conceptual development, and those which arise on account of distraction or fatigue. These three types will be designated E_1 , E_2 , and E_3 , respectively. It is assumed further that normal readers are, for the most part, not subject to errors of type E_1 , the only exceptions possibly being the two boys (one in Group I and one in Group II) who produced orientation errors on the Schonell Spelling Test. Of the remaining 28 normal readers, four made one error in judging left and

right on Test 4a, two made two errors, and two made six errors. The 20 errors produced by these eight subjects are presumed to consist of a combination of types E_2 and E_3 . It is evident that the two subjects who each made six errors make a contribution to the overall error rate which is out of proportion to their numbers; when included in the group the error rate is $20/(28 \times 8) = 0.089$, and when they are excluded it becomes $8/(26 \times 8) = 0.039$. For the purposes of this demonstration it is more important to determine the value of error rate which yields realistic results for the group as a whole than to take account of a relatively small number of atypical response patterns. As shown below, reasonably close agreement between predicted and observed results is obtained when the lower of the two error rates (0.039) is adopted, and the two subjects with scores of six were therefore excluded from the analysis.¹ Thus, if one assumes an overall error rate of 0.039 for the remaining 26 normal readers on Test 4a, then the probability of a subject giving eight correct responses to the series of eight questions is $(1 - 0.039)^8 = 0.727$. Hence, the number of subjects who would be expected to obtain the maximum score of 8 would be $26 \times 0.727 = 18.9$, or 19, to the nearest integer, a figure which is in close

¹ The errors produced by these two subjects probably fall in category E_2 . In many cases, errors of this type are likely to be the product of a deterministic, rather than a random process, since some children who have not reached the final stage of development nevertheless adopt consistent strategies on problems they are not yet able to solve, with the result that their errors conform to highly regular and predictable patterns. Such errors cannot be adequately handled by a probabilistic model and treating them as random could lead to misleading results. (Use of an inappropriate model probably accounts for the lack of agreement between predicted and observed results when the two subjects with an error score of six were included in the group.) Ideally, the model would be extended to take account of rule-governed errors, but it is not thought that the simpler solution of excluding the two subjects concerned invalidates the demonstration.

agreement with the number (20) who actually obtained the maximum score. Let us suppose that the retarded readers of Subgroup A are actually as advanced in their conception of left and right as the normal readers and are no more liable to distraction or fatigue, so that errors of type E_2 and E_3 occur at the same rate, but that there is an additional source of error due to the intermittent dissolution of the association between label and concept (type E_1). If the associative process has something in common with the maintenance of phoneme-grapheme correspondences it seems reasonable to assume that errors of type E_1 occur with approximately the same frequency as letter orientation errors. Data bearing on the latter subject were presented in Table 3.2, but since they were based on the complete sample a further calculation will be necessary in order to determine the error rate obtaining in Subgroup A. Of the 13 members of this Subgroup, 12 made orientation errors involving the letters b, d, p, q, or g, while the thirteenth inverted the letter u. Since the original analysis in terms of errors/opportunity was confined to letters in Set 1, the one which is about to be described is similarly restricted. (In order to take account of the number of opportunities for inversion of u (and n) it would be necessary to re-analyse the results of the spelling test.) Basing the calculation of the error rate in Subgroup A on the results obtained by 12 of its 13 members, the number of opportunities for errors involving letters in Set 1 was 210, while the actual number of errors was 18 (13 reversals, 4 rotations, and 1 inversion), yielding an error rate of 0.086. (This figure is, of course, higher than that given in Table 3.2 since the original analysis of Set 1 orientation errors was based on the number of opportunities available to the complete sample of retarded readers.)

It will be assumed further that the three types of error incurred by retarded readers in the three-block problem are statistically independent. In other words, on each occasion that the subject makes a judgment about the relative position of the blocks the occurrence or non-occurrence of any one of the three error types E_1 , E_2 , and E_3 has no effect on the occurrence of the remaining two. In general, for each judgment made, the probability that one or other of the error types, or some combination of them, occurs is given by:

$$p(E_1 + E_2 + E_3) = p(E_1) + p(E_2) + p(E_3) - p(E_1)p(E_2) - p(E_1)p(E_3) - p(E_2)p(E_3) + p(E_1)p(E_2)p(E_3).$$

Now, the pairwise joint events E_1E_2 , E_1E_3 , E_2E_3 , being the products of two errors, effectively result in a correct response, so that for the purposes of determining the overall error rate the corresponding joint probabilities ($p(E_1)p(E_2)$, etc.) may be dropped from the right-hand side of the above equation. Though the joint occurrence of the three types of error is equivalent to an error its probability is orders of magnitude smaller than the sum of probabilities and it too may be neglected. In this particular instance, therefore, the above equation reduces to:

$$p(E_1 + E_2 + E_3) = p(E_1) + p(E_2) + p(E_3).$$

Separate estimates of $p(E_2)$ and $p(E_3)$ are not available but their sum may be deduced from the following equation:

$$p(E_2) + p(E_3) = p(E_2 + E_3) + p(E_2)p(E_3).$$

Once again the product term may be neglected since the joint event to which it corresponds is equivalent to a correct response. As far as the probability of the union of E_2 and E_3 is concerned, its value is assumed to be the same as that calculated previously for the normal readers, viz., 0.039, while the probability of E_1 is assumed to be equal to the frequency of letter orientation errors (0.086) calculated above for Subgroup A of the retarded readers. Thus,

$$\begin{aligned} p(E_1 + E_2 + E_3) &= p(E_1) + p(E_2 + E_3) \\ &= 0.086 + 0.039 \\ &= 0.125. \end{aligned}$$

Therefore the probability of a member of Subgroup A achieving the maximum score of eight on Test 4a is $(1 - 0.125)^8 = 0.344$, and the number of subjects who would be expected to obtain this score is $12 \times 0.344 = 4.12$ (4). The number of subjects who actually obtained an error-free performance on Test 4a was the same - namely, four. Thus, errors in the use of the projective terms left and right of the type that are thought to be due to an intermittent flaw in the labelling process occur with about the same frequency as letter orientation errors. Whether it is legitimate to conclude that Subgroup A's inferior performance on the projective tests is in fact attributable to a deficit in verbal labelling, and not a conceptual deficiency, is another matter. From a theoretical standpoint, the second interpretation is more difficult to sustain than the first because, as noted above, although retarded readers who produce orientation errors are less advanced in the acquisition of projective concepts, the majority are nevertheless at a stage which should enable

them to distinguish between a figure and its left-right or up-down mirror image. On the other hand, the conceptual aspect cannot be completely ignored because even if the difficulty is one of maintaining the correct association between a verbal label and its referent it remains to explain why the associations which are most liable to disruption are those in which the identity of the referent is determined by the projective relationship of its constituent elements. To determine which of these two interpretations is correct it would be necessary to carry out an experiment of the kind described above in which the comprehension of projective relations is assessed by means of both verbal and non-verbal tasks. If the verbal deficit hypothesis is correct, retarded readers who produce orientation errors would be expected to show a greater divergence between their levels of performance on the verbal and non-verbal tasks than do those who are free of such errors.

Assuming that a solution could be found to the above problem, the main issue remaining would be to establish the direction of association between the level of spatial thought (in particular, that aspect of it involving projective relations) and the level of reading ability. In the analysis developed in Chapter 1, the processes underlying the development of the frame of reference were formulated in a way which allows the direction of this association to be freely specified, thereby permitting the model to be linked with more specific aetiological factors once the latter have been identified. The initial hypothesis was that the tendency for some retarded readers to reverse and invert letters might be attributable to the fact that the phenomenal form of a figure is more or less invariant under spatial

transformation. This characteristic of their perception was open to two interpretations, the first being that it represents an inherent perceptual deficit and the second that it stems from inadequate contact with the printed word and as such is a consequence of the reading difficulty rather than a cause of it. However, the experiment described in Chapter 4 showed that it is incorrect to suppose that there is an association between the incidence of letter orientation errors and the degree to which the phenomenal form of a figure varies under spatial transformation. On the other hand, an association was found between the incidence of letter orientation errors, the level of reading ability, and the comprehension of projective relations, so that while these findings make it necessary to revise the initial hypothesis concerning the origin of orientation errors, it still remains to determine the direction of association between the second and third factors above. The resolution of this issue is to a certain extent complicated by the fact that a satisfactory explanation has yet to be given of the relation between the level of projective development and the occurrence of letter orientation errors. Nonetheless, a start can be made by discarding a number of possible interpretations on the basis of the existing evidence.

Although, in the initial form of the hypothesis, the direction of association between the level of projective development and the level of reading ability was not predetermined, it was assumed that letter orientation errors result from a deficiency in some aspect of the frame of reference. However, to ensure that the analysis is complete it may be expedient to assume a more general model in which the direction of association between every pair of factors is left

unspecified. Such a model would allow for the possibility that letter orientation errors are a direct function of the level of reading ability, or, in other words, that they are simply the consequence of limited exposure to reading materials and insufficient opportunity to consolidate phoneme-grapheme correspondences. This interpretation would appear to bear examination in view of the finding that Subgroup A (orientation errors present) was significantly less able in reading and spelling by comparison with Subgroup B (orientation errors absent). However, Subgroup A was also less advanced in terms of projective development, so that unless this finding is to be regarded as purely fortuitous, it would be necessary to also account for it in terms of the difference in reading ability. This solution seems most unlikely because the six-month disparity in reading and spelling ability between Subgroups A and B could hardly give rise to a significant difference in the levels of projective development when the thirty-month disparity between Subgroup B and its control results in no difference at all. So, although the earlier model envisaged that certain components of the frame of reference might be acquired through exposure to text, the actual pattern of results, in which a proportion of the retarded readers are seen to be at the same level of projective development as the normal readers, makes it unlikely that reading ability is the determining factor.

Notwithstanding the above considerations, two aspects of the results could be construed as evidence of an effect of reading ability, or reading experience, on projective development. The first was that, whereas Subgroup A is inferior to B in the comprehension of left-right and above-below relations, they are on a par with each other in their

understanding of the further-nearer relation. A pattern of results of this kind is consistent with the fact that text occupies only the first two of these dimensions and that knowledge of relations within the third dimension is irrelevant to the task of reading. On the other hand the explanation could equally well be that judgments of further-nearer are assisted by perceptual cues such as the relative size and visibility of the objects concerned and that equally salient cues are unavailable in the case of the other two relations. Consequently, if members of Subgroup A are suffering from a conceptual deficit, they would not be as well-equipped to deal with the more abstract nature of left-right and above-below relations.

Further evidence to suggest that reading ability may have an effect on projective development was obtained from the analysis of the relationship between projective and euclidean development. It was shown that the correspondence between the levels reached in the comprehension of left-right relations and the conceptualization of euclidean space is closer in retarded readers than it is in normal readers. This pattern of results is just the opposite of what would be predicted if projective and euclidean concepts normally develop in close association with one another, but are out of phase in some retarded readers on account of the delayed development of projective concepts. However, it does accord with the hypothesis that retarded readers are at a pre-literate phase of development in which positions on the scales of projective and euclidean development exhibit the expected correspondence, and that the normal readers have gained an advantage in projective development through their more extensive contact with print. (They gain no advantage in terms of euclidean

development because the non-graphic environment is equally well-endowed with horizontal and vertical elements.) Unfortunately, this hypothesis suffers from the limitation mentioned earlier, which is that it cannot adequately explain why the retarded readers of Subgroup B are no less advanced than the normal readers to whom they are matched. In any event it may be premature to accept the results of the correlation analysis as they stand, given that one aspect of spatial development was assessed using a verbal measure and the other by means of a non-verbal test. Accordingly before this line of enquiry could be developed further it would be necessary to ascertain whether similar results are obtained when the assessment is based on a non-verbal measure of projective development.

Returning to the question of the relationship between the presence or absence of orientation errors, the level of projective development, and reading ability, the second interpretation to be considered is derived from the first, but involves a slight modification. On this view, it is assumed that orientation errors are not directly related to the level of reading ability but depend on the state of development of projective concepts, the latter, though, still being a function of reading ability. The advantage of this explanation is that it eliminates the fortuitous relationship between the presence or absence of orientation errors and the level of projective development, which was a feature of the first interpretation. However, it does not remove the other defect, namely the unlikelihood of reading ability being the determining factor in the level of projective development.

If letter orientation errors are not simply the product of the level of reading ability, then they are either consequent on the level

of projective development (the conceptual deficit hypothesis) or related to some other factor, such as verbal labelling ability, which also manifests itself in the different levels of performance of Subgroups A and B on the projective measures. The relative merits of these two hypotheses have already been discussed, and while no firm conclusions were reached, the more likely explanation would appear to be that there is deficiency in verbal labelling. If such a deficiency affects only a proportion of retarded readers and is superimposed on, or even disjunct from, other contributory factors, there would be no difficulty in explaining the fact that they are relatively retarded in terms of projective development, while other retarded readers - those who are free of orientation errors - are as advanced as normal readers. The hypothesis of a deficiency in verbal labelling ability is also consistent with the finding that members of Subgroup A have poorer vocabularies than members of B. Apart from the fact that orientation errors themselves tend to depress reading and spelling levels, a verbal labelling deficit could have more far-reaching effects on the acquisition of reading skills, so that if it were superimposed on other factors, as appears to be the case in Subgroup A, it could account for the lower levels of reading and spelling ability which were found there.

7.2. Knowledge of conventional series

The second area of development in which retarded readers exhibited anomalous performance was in their knowledge of conventionally-ordered series, and this factor was found to be related to several others. Thus, the fourteen retarded readers (Subgroup C) who made more than a

total of four errors in enumerating four series (days of the week, months of the year, seasons, and letters of the alphabet) were significantly inferior to those who made less than four errors (Subgroup D) in respect of Reading Age (Accuracy), Reading Age (Comprehension), Spelling Age, Verbal IQ, Performance IQ, and their scores on seven WISC subtests: Similarities, Vocabulary, Arithmetic, Digit Span, Object Assembly, Picture Completion, and Coding. Despite these differences in intellectual abilities, the two subgroups appeared to have reached comparable stages in the acquisition of euclidean concepts and the comprehension of left-right and further-nearer, but not above-below relations. (The results of the projective tests, based on subjects' distributions on the developmental scales, are somewhat difficult to reconcile with the findings reported in Chapter 3, concerning Subgroups A and B, who were much more evenly matched in terms of Verbal and Performance IQ, but who nevertheless exhibited a difference in the comprehension of left-right, as well as above-below, relations. It would require a more detailed analysis of the data to discover the reason for this apparent anomaly.) In view of the differences in intellectual abilities between Subgroups C and D, a further analysis was carried out in which each one was compared with its own control group (see Tables 3.11 and 3.12). The findings were again somewhat unexpected in that, although C was now more closely matched, in intellectual terms, to the comparison group, it was nevertheless inferior in the comprehension of left-right as well as above-below relations. Subgroup D, on the other hand, was on a par with its control group in the comprehension of all three projective relations. Where the findings are consistent is in showing that Subgroups A and C which have nine

members in common, exhibit a deficit, relative to their controls, in respect of the same two dimensions of projective development.

Before considering the significance of the vocabulary difference between Subgroup C and D in more detail, it is worth noting that poor knowledge of series does not appear to be associated with a more general linguistic deficiency, insofar as Subgroup C did not differ from its control, or for that matter from Subgroup D, either in its knowledge of word classes or its comprehension of sentence structures which involve exceptions to the Minimum Distance Principle.

Despite the fact that the difference in Verbal IQ between Subgroups C and D was larger than that between A and B, the difference in vocabulary between the first two subgroups, though significant, was smaller than that between the second two.¹ On the other hand, unlike the case of Subgroup A, C's vocabulary was significantly lower than that of its control. With a view to resolving this conflicting evidence concerning the specificity of the lag, a further comparison was undertaken in which subjects' vocabulary scores were referred to their own mean of subtest scores, as was done in the case of Subgroups A and B and their respective controls. In computing the means, Arithmetic and Digit Span scores were again excluded as they would have had the effect of attenuating the retarded readers' means by a disproportionate amount. A further refinement was introduced into the calculations to allow for the fact that Subgroup C's means of

¹ It may be remarked in passing that this pattern of results tends to support the notion advanced earlier that at least some members of Subgroup A are experiencing a specific weakness in vocabulary, allied to a verbal labelling deficit, whereas Subgroup C includes relatively more subjects whose lower vocabulary level is commensurate with their other intellectual abilities.

subtest scores were significantly lower than those of D. In these circumstances a deviation of a given magnitude assumes a greater significance in relation to the smaller of the two means, and in order to compensate for this bias the comparisons which are about to be described are based on the proportional deviation, that is, the ratio of the deviation to the mean of subtest scores. (This procedure was not necessary in the case of Subgroups A and B as their means of subtest scores were much more closely matched.) The comparison is further complicated by the fact that the normal readers include six subjects (three members of C's control group and three members of D's control group) who each made more than four errors on the series test. Had the means of the proportional deviations for each Subgroup and its control been compared by means of the t statistic the scores obtained by these six subjects might have distorted the outcome, and a factorial design was therefore adopted (see Appendix C) similar to that employed in Chapter 6 to analyze the effect of Reading Ability and Knowledge of Series on digits forward score. Although it is not so important to equalize the mean ages of the subgroups when the criterion variable is a proportional deviation based on standardised scores, Group III normal readers were again excluded in order to achieve a better balance between the numbers in each cell. The Subgroup C subject who was excluded from the Chapter 6 analyses through failure to complete the serial acquisition task was included in this one, but the two eldest members of Subgroup D were again excluded so that C and D each had 14 members. It may be seen from Table C1 that the proportional deviation of vocabulary scores is not significantly greater in those with poor knowledge of series than in those with relatively good

knowledge, a finding which applies to retarded and normal readers alike. Moreover, even though the retarded readers exhibit a negative deviation and the normal readers a positive deviation, the difference again fails to reach a significant level.

In carrying out an analysis of the kind described above, information on absolute vocabulary levels is lost. However, it is fairly clear that the 1 point difference in scaled score between Subgroup C and its control (see Table 3.10) cannot account for the poor knowledge of series exhibited by the former group. If proof of this claim is required, it can be demonstrated by examining the results of the Series Test for the 15 normal readers (Verbal control) who obtained a Vocabulary scaled score of 12 or less. The average age of this group was 6 months higher than that of C ($t = 1.36$, $df = 27$, NS), while its mean vocabulary score (10.9) was slightly lower ($t = -0.65$, $df = 27$, NS). The normal readers made an average of only 1.7 errors on the Series Test, whereas the retarded readers of Subgroup C made 12.6, or about 7 times as many, the difference between the two groups' scores being highly significant (Mann-Whitney U Test: $p < 0.001$ (1-tail)). There can be little doubt, therefore, that the limited knowledge of series found in some retarded readers constitutes a specific verbal deficit when viewed in relation to either their general vocabulary or their syntactic ability.

A similar analysis may be made of performance on the Digit Span subtest. It will be recalled from Chapter 6 (Section 6.3) that, while knowledge of series bears no relationship to performance on a serial acquisition task, it does appear to depend on the capacity of auditory short-term memory defined in terms of the forward digit span.

Even so, there was no evidence either of association between reading ability and digit span (forward) or of an interaction between reading ability and knowledge of series. As pointed out in Chapter 6, the composition of the subgroups in the two-factor design was such as to attenuate the effect of reading ability, and in particular it obscured the large difference in Digit Span score between Subgroup C and its control (see Table 5.10). A further point to consider is that the criterion variable in the analysis of variance of Section 6.3 is a raw score, whereas the data of Table 5.10 are in the form of scaled scores, which, according to the original standardization, are distributed normally at each age level with a mean of 10 and SD of 3. Since the normal readers included in the analysis of variance were, on average, younger than the retarded readers (on account of the exclusion of Group III subjects in the former category), this imbalance also had the effect of reducing the difference between their mean scores. In order to ascertain how these features of the two-factor design influenced the outcome and, in addition, to examine the question of whether Subgroup C may be considered to suffer from a specific deficit in short-term memory, a series of 2 x 2 (Reading Ability x Knowledge of Series) analyses of variance was carried out using four different forms of criterion variable, all of which, however, were based on the results of the Digit Span subtest. In the first of these analyses the two-factor design of Section 6.3 was repeated with the digit span (forward) raw score as criterion variable, instead of the transformed variable, though it was thought unlikely that a change in the scale of measurement would significantly affect the outcome. In fact, the F ratios associated with the main effects

and interaction, shown in Table D1 of Appendix D, were similar to those obtained in the original analysis.

The analysis was next carried out using the sum of raw scores on digits forward and digits backward as the criterion variable. As shown in Table D2 of Appendix D, this modification had the expected effect of increasing the F ratios for both main effects, though the effect of Reading Ability still fell short of significance.

As intimated above, the use of scaled scores as criterion variable, instead of raw scores, would be expected to amplify the effect of Reading Age, and this prediction was borne out by the third analysis (see Table D3 of Appendix D) which showed a significant difference between the retarded and normal readers ($F(1, 43) = 6.09, p < 0.05$). Although the effect appears to be less pronounced than that of Knowledge of Series, a comparison of this sort is complicated by the fact that, whereas the retarded and normal readers are of comparable intelligence, subjects with poor knowledge of series are of lower intelligence than those with better knowledge. The magnitude of the difference in the case of the retarded readers is apparent from the data of Table 5.10, which shows that the mean Verbal and Performance IQs of Subgroup D are both some 10 points higher than in Subgroup C. These differences are mirrored in the scores of the normal readers: Subgroup C' (a_2b_1) obtained a mean Verbal IQ of 111 and a Performance IQ of 107, while for Subgroup D' (a_2b_2) the mean IQ was 120 on both scales. This imbalance in the subgroups' characteristics suggests the need for a further analysis of the type carried out above in relation to Vocabulary, in which the Digit Span scaled score is referred to the mean of subtest scores, thereby establishing whether

the more limited capacity of auditory short-term memory should be construed as a specific deficit. In computing the mean of subtest scores for this analysis, the Arithmetic score was excluded since the inferior performance of some retarded readers, particularly those in Group III, has the effect of masking the presence of putative deficits in other areas. As before, the criterion variable was based on the proportional deviation, that is, the ratio of the deviation to the mean of subtest scores. As the analysis in Table D4 shows, by applying this transformation to the scaled score and thereby effectively controlling for IQ, the magnitude of the F ratio describing the effect of factor B, Knowledge of Series, is reduced to about the same level as that describing factor A, Reading Ability, both ratios being larger than the critical value for a 0.05-level test.

What the results of the preceding analysis suggest is that the retarded readers are characterized by a specific deficit in auditory short-term memory, which assumes more significant proportions in those with poor knowledge of series. An equally strong relationship between knowledge of series and the relative capacity of auditory memory was found in normal readers. Even so, it is not immediately apparent from the figures given in Table D4 why the normal readers of Subgroup C' have failed to master common series since their proportional deviation is not appreciably lower than that of the retarded readers with relatively sound knowledge of series. However, a comparison based on proportional deviations does not give the complete picture, since the former group, being of lower mean IQ than the latter, would have been under a greater handicap by virtue of the fact that their absolute span of recall is shorter. Indeed, the same applies to members of Subgroup C

by comparison with those in D. Thus, irrespective of their reading ability, subjects in the lower part of the intellectual range appear to be doubly handicapped: not only are their Digit Span scores lower in absolute terms, they are also lower in relation to the level of their other intellectual skills. This pattern of results may not necessarily indicate that those of lower IQ suffer from a disproportionate limitation on the capacity of short-term memory per se, but rather that those of higher IQ are able to make more effective use of the same capacity, for example, by adopting suitable mnemonic strategies.

Despite the fact that Subgroups A and C have a significant number of members in common, the difference in auditory short-term memory between C and D (see Table 5.8) is no longer in evidence when the capacities of A and B are compared (see Table 3.10). When the reasons for this apparent inconsistency were analysed, it was found to be a consequence of the fact that, in going from Subgroup A to Subgroup C four subjects with a mean Digit Span score of 10 (corresponding to a proportional deviation of -0.223) are lost, while five subjects with a mean score of 6.8 (corresponding to a proportional deviation of -0.392) are gained. The four subjects who were members of A but not C were of above average intelligence (Mean VIQ = 115; Mean PIQ = 121), but in their conception of left and right they were relatively immature, which could explain their predisposition to make orientation errors. (Of the four, two had advanced no further than Stage O-IB, one was at Stage II, while the performance of the fourth could not be classified - he achieved complete success on Tests 1, 2, 4a and 4b, but made two errors on Test 3 (identification of left and right on the

examiner's body).) The five subjects who were members of C but not A included one who was a member of neither A nor B, having been unable to attempt a single word on the Schonell Test. The remaining four were of average intelligence (Mean VIQ = 110; Mean PIQ = 108), but as a group appear to be distinguished by the fact that three of them exhibit a positive deviation when the vocabulary score is compared with the mean of subtest scores. Altogether, only five members of Subgroup C (N = 15) and four members of A (N = 13) achieved a vocabulary score higher than the mean of subtest scores, and if, as suggested earlier, this characteristic reflects the efficiency of the process whereby verbal labels are linked to their referents, it may partly explain why the four members of C who are not in A are less liable to make orientation errors. The present sample is obviously too small to pursue this kind of analysis in a rigorous fashion, but if the trends outlined above are anything to go by, it would probably be a mistake to regard Subgroups A and C as homogeneous, insofar as the aetiological factor (or combination of factors) which determines membership of a particular Subgroup may well vary from one individual to another within that Subgroup.

Notwithstanding the fact that children's knowledge of series depends on the capacity of auditory short-term memory, it apparently bears no relationship to performance on a serial verbal learning task, except in the case of normal readers with poor knowledge of series who experience a disproportionate degree of difficulty in recalling relatively abstract items (Med. m nouns) on trial 1. This finding suggests that, in general, the ease with which series are acquired does not depend on the effectiveness of rehearsal strategies or the

efficiency of long-term retention and retrieval processes. The fact that the difference in Digit Span score between those with poor knowledge of series and those with good knowledge is not reflected in the number of items retained on trial 1 of the serial acquisition task is perhaps not surprising, since the length of the inter-item interval was such that, however many items were in short-term store, they would probably have been lost unless the subject engaged in verbal rehearsal, so that the main function of the store in this type of task would probably be to retain the last item presented, something which should be within the capacities of all subjects.

Although the serial learning task failed to differentiate those with poor knowledge of series from those with good knowledge it was much more difficult for the retarded than for the normal readers, except in the case of the list comprising concrete words of high meaningfulness, where the acquisition rate over the complete series of trials (but not the number of items acquired on trial 1) was not significantly different from one group to the other. One explanation of these findings might be that the normal readers are able to encode the items orthographically, a strategy which would be especially useful in the case of items for which visual images are not readily available. However, if the efficiency of orthographic encoding were one of the main features determining the ease of acquisition one would expect normal readers to find lists of CVC nonsense syllables no more difficult, and possibly somewhat easier to learn than lists of disyllabic nouns. The only piece of evidence that an effect of this sort might be operating was found in the case of normal readers with poor knowledge of series who retained more items on trial 1 of

the list of High m' nonsense syllables than on trial 1 of the list of Med. m nouns. However, it is believed that other factors were at work here, because the High m nouns, which were orthographically about as complex as the Med. m nouns, were much easier to retain than either the Med. m . nouns or the High m' syllables, while the Low m' nonsense syllables, which were orthographically not a great deal less familiar than the High m' syllables were nevertheless appreciably more difficult to remember. Thus, in general, the simpler orthography of the nonsense syllables in no way compensated for their lower meaningfulness; for the retarded readers and also the majority of normal readers acquisition rates were an increasing function of word meaningfulness, despite the fact that the less meaningful nonsense words were orthographically more simple.

If it is correct to assume that there are negligible differences in I and C between the lists of High m' and Low m' nonsense syllables, it would follow that acquisition rates within a given subgroup are primarily a function of item meaningfulness, unless the variation is the expression of changes in some other attribute or attributes which have not been taken into account. Now it is evident from Fig. 6.1 that there is no interaction between reading ability and m' ; in other words, the effect of a change in m' on acquisition rate is approximately the same for retarded readers as for normal readers. This being the case, it suggests that the lower acquisition rates achieved by retarded readers under both conditions (High m' and Low m') are the consequence of the less efficient encoding of an attribute yet to be identified. Otherwise, in order to give an explanation solely in terms of meaningfulness, it would be necessary to assume that the verbal

associative process is intrinsically as efficient in one group as the other, but that its full potential is not realized in retarded readers because the effective value of m' for a given item assumes a much lower value than it does in the case of normal readers. In other words, although there is the same probability that an implicit verbal association will be capable of facilitating an inter-item connection, the number of implicit associations which a given item evokes is smaller in retarded readers than in normal readers. If this interpretation were correct, it would presumably be possible to infer how much lower the mean effective value of m' is in retarded readers by comparing their acquisition rates on the different lists with those of the normal readers. However, this argument leads to the unlikely conclusion that the meaningfulness of Med. m nouns for retarded readers is less than that of High m' nonsense syllables for normal readers (see Fig. 6.1), and it is therefore fairly certain that the encoding process which is at fault in retarded readers involves an attribute or attributes other than verbal associative meaningfulness.

As Paivio admits, the dual coding hypothesis is not a complete model of memory, one of its chief purposes being to extend the scope of other contemporary models by going beyond the almost exclusive emphasis on auditory-motor verbal memory and analysing the role of imagery. Inasmuch as the dual coding hypothesis is concerned with verbal and imaginal processes, its primary focus is on dimensions of stimulus meaning with less attention being given to acoustic and articulatory processes and their relationship to the phonological level of language. However, the work of Spring and Capps (1974) referred to earlier has shown that retarded readers' inferior short-term memory for verbal material might be attributable to the fact

that the phonological elements are encoded much more slowly than in normal readers, so that there is less time available for rehearsal between items. Since the efficiency of the rehearsal process also governs the rate at which items can be transferred from short- to long-term store, it is likely that long-term memory tasks would also be impaired. The way in which Spring and Capps assessed the speed of phonological encoding was by asking subjects to name series of digits, colour patches, and pictures, as rapidly as possible. The normal readers were able to name all three types of stimulus more rapidly than the retarded readers, the superiority of the former group being particularly marked in the case of digits. Memory was assessed by means of a probe-recall task in which a series of 8 visually presented digits were shown one at a time from left to right for a period of 1.5 seconds each. It was found that naming speed accounted for a significant proportion of digit recall variance.

There is evidence to suggest that other aspects of the phonological encoding process may be impaired in retarded readers. For example, Bradley and Bryant (1978) showed that 10-year-old retarded readers have much greater difficulty than 6-year-old normal readers at the same stage of reading in analysing and comparing the phonetic structure of words. The subjects' task was to listen to a set of four monosyllabic words, three of which had a sound in common in the same position, which the fourth did not share, and to say which was the odd one out. There were three series, with six four-word sets in each. The sound which three of the words had in common occupied a different position in each series, i.e., initial, medial, or final. Combining the results from all three series, 92% of the retarded readers made at least one error,

while 85% made two or more. By comparison, 53% of the normal readers made one or more errors and only 27% made two or more. The relevance of this finding to an understanding of the reading process is that the child has to develop an awareness of the phonetic structure of speech in order to be able to map the alphabetic symbols onto the corresponding phonological elements. This aspect of the process has also been studied by Bruce (1964), Mattingley (1972) and Zhurova (1963), while recent work by Liberman, Shankweiler, Liberman, Fowler, and Fischer (1976), Liberman and Shankweiler (1979), and Shankweiler and Liberman (1976) has shown that the phonetic segmentation of speech is impeded in some retarded readers by a deficiency in phonetic encoding in auditory short-term memory. In the present study errors incurred in the serial learning tasks were not formally analysed but it was noticeable, particularly in the case of the lists of nonsense syllables, that retention of the items themselves presented more of a problem to the retarded readers than their correct ordering. The most common type of mistake, frequently repeated from trial to trial, involved the substitution of an incorrect phoneme in one position. The effect of these substitutions was often to transform the nonsense syllable into a word, suggesting that the retarded readers were relying on semantic associations in an attempt to compensate for what could be a deficiency in the phonological encoding process.

The hypothesis of a deficiency in phonological encoding would clearly need to be elaborated in order to account for the present pattern of results. More than one factor seems to be at work because, while there is a tendency for the deficiency in auditory short-term memory to be associated with poor knowledge of series, irrespective of

the level of reading ability, the impairment in long-term serial acquisition is a characteristic which is confined to retarded readers but apparently unrelated to their knowledge of series. One possible explanation, in the light of the findings reviewed above, might be that recall of auditory information from short-term store is largely a function of the speed of phonological encoding, whereas long-term retention of non-meaningful verbal information is more dependent on the accuracy of encoding, with these two aspects of the process being relatively independent of each other.

7.3 Conclusion

A theoretical model was developed in an attempt to explain several anomalies of visual perception and oral language which are said to occur in cases of reading retardation. These phenomena include: persistent errors in letter orientation in reading and writing; delayed acquisition of conventional series (e.g., months of the year); conceptual confusions in which an antonym is substituted for the correct adjective, adverb, or verb; and the ability to recognize complex forms (e.g., words or faces) when seen in a novel orientation with the same ease as when upright. It was argued that these anomalies arise from a unitary psychological deficit in which the visual system fails to establish or maintain an intrinsic frame of reference.

The incidence of the above anomalies in a group of 9- to 12-year-old boys retarded in reading was compared with that in a matched group of normal readers. Two aspects of syntactic development were

also assessed in order to establish whether or not the linguistic anomalies listed above, if present in the sample, are part of a more general delay in language acquisition. Differences were found between the two groups with respect to the frequency of orientation errors and knowledge of common series, though not in form recognition under spatial transformation, the acquisition of adjective-antonym pairs, or knowledge of syntactic rules.

With a view to determining whether the higher incidence of orientation errors and poor knowledge of series in retarded readers is attributable to a deficiency in spatial thought, the state of development of the frame of reference was assessed by means of two measures derived from the work of Piaget and Inhelder, one relating to the child's conceptions of the horizontal and vertical and the other to his knowledge of projective relations (above-below, left-right, and further-nearer). Overall, there were no differences between the two groups on either measure. However, when the retarded readers who made errors in letter orientation were compared with those who made no such errors, and also with the normal readers who served as controls, some differences in the predicted direction emerged. Moreover, the first subgroup (orientation errors present) was inferior to the second (orientation errors absent) in vocabulary and reading and spelling ability, but there were no differences in respect of form recognition under spatial transformation, or knowledge of syntax (the findings concerning conceptual confusions were inconclusive).

On assigning the retarded readers to two subgroups according to their degree of familiarity with conventional series, those with

relatively poor knowledge (a group which included 70% of those who made orientation errors) were found to have inferior short-term memory, lower vocabulary level, and less advanced projective concepts, relative to their controls, though there was no difference in the level of syntactic development. In contrast, the retarded readers with better knowledge of series reached the same level of performance as their controls on all the measures examined.

It may be tentatively concluded that persistent errors in letter orientation and poor retention of conventional series are both associated with a delay in the acquisition of projective concepts. Although these results are in agreement with the predictions, certain other findings throw doubt upon the explanation originally put forward. In the first place, there was no evidence to suggest that the occurrence of orientation errors is related to an anomaly of perception in which the change in phenomenal form of a figure under spatial transformation is less pronounced than usual. (Even so, until a more comprehensive model of the letter identification process has been evaluated it may be premature to reject the notion that, for retarded and normal readers alike, changes in orientation are perceived in terms of changes in phenomenal form.) Secondly, the fact that the retarded readers who made orientation errors were found to have poorer vocabularies than those who did not suggests that linguistic as well as spatial factors are involved. On this view, the apparent lag in the acquisition of projective concepts could be interpreted as being due to an impairment, albeit a subtle one, in the naming process. At the same time, the poor knowledge of series found in a proportion of retarded readers (chiefly those who made errors in orientation) is not part of a general

delay in the acquisition of language, insofar as syntactic abilities are normal. Although vocabulary level was slightly lower and comprehension of projective relations less advanced in this subgroup, there was also evidence to suggest that an impairment in auditory short-term memory may have limited retention, at least in some cases.

A serial learning task, designed to simulate the acquisition of conventional series, for the most part failed to reveal any differences between those with better knowledge of series and those with poor knowledge, though it did differentiate between the retarded and normal readers. The explanation of this pattern of results remains to be determined.

Appendix AThe derivation of multiple regression equations for the prediction of reading age in Cambridgeshire Junior school boys

Two sets of linear equations were generated to describe the association between reading age, chronological age and IQ, one applying to the lower part of the age range, and the other to the upper part. Although no formal tests were made, there was reason to believe that the relationship between criterion and predictor variables was non-linear, and the range was therefore sub-divided in an attempt to reduce the magnitude of the resulting error. The lower part of the range included boys who were in the first and second year at the time the WISC and Neale Analysis were taken, while the upper part included those who were in the third and fourth years.

There were four categories of boys in each sample: (1) members of the control groups, (2) boys who took the Stage III tests as prospective members of the control groups but were not selected, (3) boys who met the criterion for reading retardation at Stage II but failed to meet it at Stage III and who, for the most part, were moderately retarded in reading, and (4) members of the retarded reader groups. The individuals in these four categories together comprised about 42% of all boys in the classes taking part. In assembling the samples every member of categories (1) to (3) was included, but some retarded readers were excluded in order to obtain a representative sample. Thus, on the assumption that the screening procedure had succeeded in identifying virtually all the male retarded readers in the population, their total number was reduced by a factor equal to the ratio of the size of the sample to the size of the population.

One of the assumptions underlying multiple regression analysis is that the data describe a random sample of individuals. However, it is doubtful whether this condition was fully satisfied here, for the selection procedure almost certainly resulted in some sections of the reading ability and IQ ranges being over-represented, while the extremes of the ranges were scarcely represented at all since no Independent schools or schools for the ESN were included. Nevertheless, as shown below, the relevant variables are distributed in an approximately normal form (with the exception of RA (Acc) and RA (Comp) in the upper part of the age range, where they exhibit a pronounced negative skew), while the standard errors of estimation are quite close to the values found in the IoW study.

The composition of the samples and the derivation of the multiple regression equations are described in the following two sections, which present separate analyses for the lower and upper parts of the age range.

First and second year sample

The composition of the sample is shown in Table A1, together with information on the number of pupils in the age range at the schools concerned. First year boys were drawn from one group of three schools and second year boys from another group of three (see Table 2.3). Since information on class sizes obtained at the time of the study did not include separate figures for each sex, the number of boys was estimated on the assumption that the sex ratio is 1:1. In order to establish the number of retarded readers to be included in the sample, the total number recruited in each year was prorated by a factor equal

to the number of boys in categories (1) to (3) in the sample, divided by the number of boys in the year who were not retarded in reading (the resulting figure being rounded to the nearest interger). The denominator of this factor was computed by subtracting the total number of retarded readers from the total number of boys in the year, on the assumption that all those who were not retarded readers would have been candidates for one of the other three categories. Thus, for the first year sample: $N = 11 \times 37 / (90 - 11) = 5.15$ (5); and for the second year: $N = 9 \times 36 / (137 - 9) = 2.53$ (3).

The multiple regression equations are based on a statistical model in which it is assumed that the criterion variable (in this case, RA) is a linear function of the predictor variables (CA and IQ) and a random variable (ϵ) which is normally distributed and independent of the predictor variables:

$$RA = \alpha_1 + \alpha_2 CA + \alpha_3 IQ + \epsilon \quad (1)$$

The standard deviation of ϵ is termed the standard error of estimate ($S_{1.23}$). It can be shown (Ferguson, 1959) that:

$$\alpha_1 = \bar{RA} - \beta_2 s_1 / s_2 (\bar{CA}) - \beta_3 s_1 / s_3 (\bar{IQ}), \quad (2)$$

$$\alpha_2 = \beta_2 s_1 / s_2, \quad (3)$$

and $\alpha_3 = \beta_3 s_1 / s_3, \quad (4)$

where s_1 , s_2 , and s_3 are the SDs (in terms of raw scores) of the distributions of RA, CA, and IQ, respectively, and:

$$\beta_2 = \frac{r_{12} - r_{13}r_{23}}{1 - r_{23}^2} \quad (5)$$

$$\beta_3 = \frac{r_{13} - r_{12}r_{23}}{1 - r_{23}^2} \quad (6)$$

In the above equations for β_1 and β_2 , r_{12} , r_{13} , and r_{23} are the two-variable correlation coefficients describing the association between RA (var. 1), CA (var. 2), and IQ (var. 3).

The standard error of estimate (in terms of raw score units - in this case, months) is given by:

$$S_{1.23} = \sqrt{(N - 1)s_1^2(1 - R_{1.23}^2)/(N - k - 1)} \quad (7)$$

$$\text{where } R_{1.23} = \sqrt{\beta_2 r_{12} + \beta_3 r_{13}}, \quad (8)$$

N is the size of the sample,

and k is the number of predictor variables.

The parameters of the distributions of CA, IQ (short form WISC scaled score), RA (Acc) and RA (Comp), for the first and second year sample ($N = 81$), are shown in Table A2. Knowing the mean and SD of each of these variables the raw scores were converted to standard scores. Pairwise correlations were then carried out between the criterion and predictor variables, using the standard scores. Considering, first, the case where the criterion variable is RA (Acc), one obtains the correlation matrix shown on the left of Table A3(i). Substituting for these coefficients in equations (5) and (6) above; $\beta_2 = 0.488$, and $\beta_3 = 0.387$, and hence $R_{1.23} = 0.608$, from equation (8). The alpha coefficients may then be determined from equations (2) - (4) and substituted in (1) to give the expected value of the criterion variable:

$$RA(\text{Acc}) = -85.50 + 1.43CA + 0.86IQ,$$

the standard error of estimate, from equation (7), being 11.49 months.

Similarly, when the criterion variable is RA(Comp) the correlation matrix has the values shown on the right of Table A3(i). It follows

Table A1. Composition of samples on which multiple regression equations were based (with supplementary information on classes from which they were drawn).

	Year			Year		
	1st	2nd	Total	3rd	4th	Total
No. of pupils in year	180	274	454	186	157	343
No. of boys in year	90	137	227	93	79	172
No. of male retarded readers recruited	11	9	20	4	6	10
Composition of sample:						
No. selected for control groups	16	12	28	7	10	17
No. screened, but not selected for control groups	19	19	38	18	27	45
No. screened, but not selected for retarded reader groups	2	5	7	3	0	3
No. selected for retarded reader groups	5	3	8	1	3	4
Total	42	39	81	29	40	69

Table A2. Parameters describing distribution of RA(Acc), RA(Comp), CA, and IQ in regression samples.

	Mean	SD	Skewness	Kurtosis
First- and second-year boys (N = 81)				
CA (mo.)	105.93	4.87	0.004	2.62
IQ (scaled score)	55.48	6.47	-0.24	2.86
RA(Acc) (mo.)	113.62	14.29	0.34	2.92
RA(Comp) (mo.)	122.75	18.06	-0.10	2.05
Third- and fourth-year boys (N = 69)				
CA (mo.)	135.43	7.89	-0.07	1.99
IQ (scaled score)	50.80	7.26	0.24	2.74
RA(Acc) (mo.)	131.41	16.14	-1.15	4.05
RA(Comp) (mo.)	139.88	16.05	-1.59	5.08

Table A3 Correlation between RA(Acc)/RA(Comp), CA, and IQ.

(i) First- and second-year boys

	RA(Acc)	CA	IQ		RA(Comp)	CA	IQ
RA(Acc)	1.000	0.469	0.363	RA(Comp)	1.000	0.498	0.426
CA		1.000	-0.050	CA		1.000	-0.050
IQ			1.000	IQ			1.000

(ii) Third- and fourth-year boys

	RA(Acc)	CA	IQ		RA(Comp)	CA	IQ
RA(Acc)	1.000	0.454	0.402	RA(Comp)	1.000	0.431	0.490
CA		1.000	0.241	CA		1.000	0.241
IQ			1.000	IQ			1.000

Table A4 Size of discrepancies (in months) between predicted and measured reading ages by various percentages of the sample.

	Proportion of sample			
	20%	10%	5%	1%
First- and second-year boys				
RA(Acc)	9.65	14.71	18.90	26.73
RA(Comp)	11.37	17.33	22.27	31.49
Third- and fourth-year boys				
RA(Acc)	11.54	17.59	22.60	31.96
RA(Comp)	11.08	16.88	21.70	30.18

from equations (5), (6) and (8) that $\beta_2 = 0.521$, $\beta_3 = 0.452$, and $R_{1.23} = 0.672$. Hence the expected value of the criterion variable is:

$$RA(\text{Comp}) = -151.91 + 1.93CA + 1.26IQ,$$

with a standard error of 13.54 months.

Third- and fourth-year sample

The preceding analysis was repeated for the upper part of the age range. As far as the composition of the sample (Table A1) is concerned, it may be noted that the entries in the first row of the Table refer to the schools where the retarded readers were recruited. A number of normal readers in this sample were selected at two other schools (Village Colleges), but it is not necessary to take their numbers into account in determining how many retarded readers should be included in the sample.

Having calculated the parameters for the distributions of the four variables, the raw scores were converted to standard scores, and two-variable correlations were then carried out to determine the coefficients shown in Table A3(ii). Considering, first, the prediction of $RA(\text{Acc})$, equations (5), (6), and (8), above, yield $\beta_2 = 0.379$, $\beta_3 = 0.311$, and $R_{1.23} = 0.545$. Hence, by substitution in (2) - (4) and then (1):

$$RA(\text{Acc}) = -8.71 + 0.78CA + 0.691IQ,$$

with a standard error of estimate (equation (7)) of 13.74 months.

When the criterion variable is $RA(\text{Comp})$, $\beta_2 = 0.332$, $\beta_3 = 0.410$, $R_{1.23} = 0.587$, and

$$RA(\text{Comp}) = 2.37 + 0.68CA + 2.37IQ,$$

with a standard error of 13.19 months.

Finally, knowing the standard errors of estimate, it was possible to calculate, for various proportions of the two samples, the margins by which their predicted reading ages exceeded the measured values, as shown in Table A4.

Appendix BIntellectual ability and educational attainment in a clinical sample of retarded readers.

The purpose of this analysis is to determine how the degree of under-achievement in the Cambridgeshire sample compares with that found in a group of boys who have undergone psychological assessment at a dyslexia clinic. Assessments at the clinic concerned are based on tests of intelligence and attainment which are the same as those used in the present study. The majority of children attending the clinic reside in London or the Home Counties. Generally speaking, applications for assessment come from the parents, though in a few cases the child is referred by the school. Different criteria are used by the psychologists who carry out the assessments in determining what degree of retardation (when viewed in conjunction with other presenting symptoms) places the difficulty in the category of dyslexia or specific reading retardation. It would have defeated the object of this exercise to re-analyse the test findings in accordance with a common criterion, and each psychologist's conclusions were therefore accepted as they stood. Their reports often contain terms other than "dyslexia" to indicate that this condition has been identified, e.g., "retarded in reading and spelling", "specific learning disability", "specific disability", "specific developmental dyslexia", "difficulty may be constitutional in nature".

The clinic sample was composed of boys whose ages, at the time of assessment, fell in one of the three ranges represented by the Cambridgeshire sample, viz., Group I: 7:10 - 8:8, Group II: 8:9 - 9:5,

and Group III: 10:6 - 11:5. In addition, a fourth clinical subgroup (IIA) was formed from boys who were intermediate in age to those in Groups II and III, i.e. in the range 9:6 - 10:5. (The ranges specified above for the Cambridgeshire sample refer to boys' ages at the time the Neale Analysis of Reading Ability was taken.) All files of boys aged 7:10 - 11:5 on hand at the clinic on 13.6.77 were examined, and where a positive diagnosis had been made the following information was recorded:

Wechsler Intelligence Scale for Children - Revised:

Subtest scores
 Verbal IQ
 Performance IQ
 Full Scale IQ

Neale Analysis of Reading Ability:

Reading Age (Accuracy)
 Reading Age (Comprehension)

Schonell Graded Word Spelling Test:

Spelling Age

The characteristics of the Cambridgeshire group and the clinical group are shown in Table B1 which gives subjects' mean scores on the relevant measures for each of the four age ranges, and for the combined range (i.e. Groups I, II, and III). With Groups I, II, and III merged the two samples were compared on each measure by means of the t test, but there were no significant differences between them except in the case of Achievement Quotient where the Cambridgeshire group obtained a significantly lower score ($t = 2.45$, $p < 0.02$ (2-tailed)). The more pronounced degree of under-achievement in the Cambridgeshire sample, which arises despite the absence of a significant difference in RA(Acc), is partly attributable to the slightly higher mean CA of this group. It may be concluded that the criterion of under-achievement adopted in selecting retarded readers for the present study is at least as strict

as that used in clinical practice to identify dyslexic children.

Table B1 Intellectual ability and educational attainment in the Cambridgeshire sample of retarded readers (Ca.) and in a clinical group (Cl.)

	Group									
	I		II		IIA	III		I-III		
	Ca.	Cl.	Ca.	Cl.	Cl.	Ca.	Cl.	Ca.	Cl.	
N	11	7	9	6	11	10	7	30	20	
CA	8:5	8:1	9:1	9:1	9:10	11:2	10:11	9:6	9:5	
MVS (SS)	28.1	27.1	27.9	25.8	25.1	25.3	23.3	27.1	25.4	
MPS (SS)	26.5	26.3	27.0	26.2	23.8	26.6	25.6	26.7	26.0	
VIQ	113.2	117.9	111.0	110.0	110.3	102.2	106.9	108.9	111.7	
PIQ	113.8	114.7	119.1	111.8	107.2	110.5	107.9	114.3	111.5	
FSIQ	114.8	118.1	116.2	112.0	109.8	106.8	108.0	112.6	112.8	
RA(Acc)	7:4	7:8	7:11	8:0	8:3	8:1	8:9	7:9	8:2	
RA(Comp)	7:9	7:11	8:6	8:4	9:0	9:1	9:9	8:5	8:8	
SA	6:8	7:0	7:4	7:1	7:7	7:1	7:9	7:0	7:4	
AQ (%)	76.2	80.4	75.3	79.3	76.9	68.9	75.2	73.5	78.3	

Appendix C

Summary of statistical procedure (ANOVA) used to examine the relationship between vocabulary, reading ability, and knowledge of common series.

This design is similar to that employed in Chapter 6 to analyse the effect of Reading Ability and Knowledge of Series on Digit Span (forward) raw score. The levels of each of the factors are as follows:

A: a_1 = Retarded Readers B: b_1 = Four or more errors on Series Test
 a_2 = Normal Readers b_2 = Less than four errors on Series Test

Since the numbers of subjects in each cell were not equal, Rao's (1952) method was used to compute adjusted sums of squares for the main effects and interaction. Details of the analysis are given in Table C1.

Table C1 Two-factor (Reading Ability (A) x Knowledge of Series (B)) design with proportional deviation of Vocabulary scaled score from mean of subtest scores (excluding Arithmetic and Digit Span) as criterion variable.

(i) Cell Means:			(ii) Cell Frequencies:			
	b_1	b_2		b_1	b_2	
a_1	-0.031	-0.025	a_1	14	14	28
a_2	0.087	0.005	a_2	6	14	20
				20	28	

(iii) Summary of analysis of variance

Source of variation	SS	df	MS	VR
A (Adj.)	0.044	1	0.044	2.089
B (Adj.)	0.008	1	0.008	
AB (Adj.)	0.020	1	0.020	
Within cell (Error)	0.924	44	0.021	

$$F_{0.95}(1, 44) \doteq 4.08$$

Appendix D

Summary of statistical procedures (ANOVA) used to examine the relationship between the capacity of auditory short-term memory, reading ability and knowledge of common series.

In Chapter 6 the relationship between the capacity of short-term memory, reading ability, and knowledge of series was investigated by means of a 2 x 2 (Reading Ability (A) x Knowledge of Series (B)) design in which the criterion variable was derived by applying a transformation of the form $X' = \log(X + 1)$ to the Digit Span (forward) raw score. A significant association was found between knowledge of series and forward digit span, but not between reading ability and forward span. However, there was reason to suppose that the true nature of these relationships was obscured both by the form of the criterion variable and the composition of the subgroups under the different combinations of levels of factors A and B. In order to elucidate the matter, a series of analyses was carried out which preserved the basic design described in Chapter 6, but entailed a number of modifications in the form of the criterion variable. Details of these analyses are given in the following Tables (D1 to D4), the exact form of the criterion variable being specified in each case. As before, the levels of each of the factors are as follows:

A: a_1 = Retarded Readers	B: b_1 = Four or more errors on Series Test
a_2 = Normal Readers	b_2 = Less than four errors on Series Test

Since the numbers of subjects in each cell were not equal, Rao's (1952) method was used to compute adjusted sums of squares for the main effects and interactions. The considerations underlying the modifications made to the form of the criterion variable, the effects of these changes on the outcome of the analysis, and the conclusions which were drawn, are discussed in Chapter 7.

Table D1 Two-factor (Reading Ability (A) x Knowledge of Series (B)) design with Digit Span (forward) raw score as criterion variable

(i) Cell Means:			(ii) Cell Frequencies:			
	b_1	b_2		b_1	b_2	
a_1	4.615	5.500	a_1	13	14	27
a_2	4.833	5.786	a_2	6	14	20
				19	28	

(iii) Summary of analysis of variance

Source of variation	SS	df	MS	VR
A (Adj.)	0.755	1	0.755	1.259
B (Adj.)	9.073	1	9.073	15.141
AB (Adj.)	0.012	1	0.012	
Within cell (Error)	25.767	43	0.599	

Table D2 Two-factor (Reading Ability (A) x Knowledge of Series (B)) design with Digit Span (forward plus backward) raw score as criterion variable

(i) Cell Means:			(ii) Cell Frequencies:			
	b_1	b_2		b_1	b_2	
a_1	7.536	8.929	a_1	13	14	27
a_2	7.833	9.714	a_2	6	14	20
				19	28	

(iii) Summary of analysis of variance

Source of variation	SS	df	MS	VR
A (Adj.)	4.055	1	4.055	3.363
B (Adj.)	27.262	1	27.262	22.609
AB (Adj.)	0.624	1	0.624	
Within cell (Error)	51.850	43	1.206	

$$F_{0.95}(1, 43) \doteq 4.08; \quad F_{0.99}(1, 43) \doteq 7.31$$

Table D3 Two-factor (Reading Ability (A) x Knowledge of Series (B)) design with Digit Span scaled score as criterion variable.

(i) Cell Means:			(ii) Cell Frequencies:			
	b_1	b_2		b_1	b_2	
a_1	7.539	9.714	a_1	13	14	27
a_2	8.333	11.643	a_2	6	14	20
				19	28	

(iii) Summary of analysis of variance

Source of variation	SS	df	MS	VR
A (Adj.)	25.303	1	25.303	6.091
B (Adj.)	74.588	1	74.588	17.954
AB (Adj.)	3.327	1	3.327	
Within cell (Error)	178.636	43	4.154	

Table D4 Two-factor (Reading Ability (A) x Knowledge of Series (B)) design with proportional deviation of Digit Span scaled score from mean of subtest scores (excluding Arithmetic) as criterion variable

(i) Cell Means:			(ii) Cell Frequencies:			
	b_1	b_2		b_1	b_2	
a_1	-0.337	-0.244	a_1	14	14	28
a_2	-0.255	-0.108	a_2	6	14	20
				20	28	

(iii) Summary of analysis of variance

Source of variation	SS	df	MS	VR
A (Adj.)	0.151	1	0.151	7.137
B (Adj.)	0.143	1	0.143	6.577
AB (Adj.)	0.007	1	0.007	
Within cell (Error)	0.935	44	0.021	

$$F_{0.95}(1, 44) \doteq 4.08; F_{0.99}(1, 44) \doteq 7.31$$

Appendix EThe judgment of egocentric orientation: Supplementary findings.

The ability to judge egocentric orientation was assessed by means of a specially designed apparatus which allowed the subject to view stimuli such as lines and points (constructed from self-powered light sources) within a horizontal plane, against a completely dark background containing no visual clues which might be used as a reference for orientation or position. The stimuli were mounted on a circular turntable which could be rotated to any desired position. In this particular experiment the stimulus was a straight line 9" long, viewed from a distance of 28", and the subject was required to make judgments about its orientation in relation to both the top-bottom and left-right axes of the head. Before commencing the experiment the examiner demonstrated the directions of these two axes by orienting a pencil in front of his face. Each child made 4 judgments of the upright and 4 of the lateral axis, one direction being alternated with the other. Initially the line was set at an intermediate position and then advanced in 5° steps until the child indicated it was in the correct orientation by calling "stop". The initial setting of the line and also the direction of rotation was varied randomly from trial to trial.

It was found that, throughout the age range, retarded and normal readers alike exhibited a high degree of accuracy in judging the line's egocentric orientation. Considering the results for Groups I - III combined, the retarded readers' (N = 30, Mean CA = 10:4) judgments of the upright were, on average, within 3.4° (r.m.s.) of the correct direction, and their judgments of the lateral axis were

within 3.9° (r.m.s.). The normal readers' (N = 30, Mean CA = 10:5) settings were within 4.3° (r.m.s.) in each case. A comparison of Subgroups A and B would not be expected to reveal anything of significance, since these errors are too small to be of any consequence in relation to the problem of letter identification.

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The Cartesian Frame of Reference: A Structure Unifying the Description of Dyslexia

Graham Richardson^{1,2}

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It is shown that six phenomena often associated with dyslexia may be attributed to the lack of a visual, Cartesian frame of reference. These phenomena are (1) reading errors due to letter reversal, inversion, or rotation, (2) form recognition of all classes of mono-oriented objects which is independent of the figure's egocentric orientation, (3) defective visual sequential scanning, resulting in confused letter and word order, (4) poor visual balance performance, (5) the failure to acquire nonspatial ordering relations, including temporal relations and tenses, and (6) the characteristic intellectual profile of severely retarded readers, namely, PIQ/VIQ greater than 1, where PIQ is the performance IQ score and VIQ the verbal IQ score on the Wechsler Intelligence Scale for Children (WISC). The latter phenomenon is dependent on (2) and (5) above. A strategy for further research is outlined.

INTRODUCTION

The investigation of Piaget and Inhelder (1956) concerning the child's conception of the vertical and horizontal of space is well known. Later, Inhelder (1962) noted that children with reading disabilities did not perform as well on the tests involved as average readers of comparable age. Inhelder's finding was confirmed by Lovell *et al.* (1964), who showed that backward

¹Department of Electrical Engineering, Imperial College, London, England.

²Requests for reprints should be sent to Graham Richardson, Unit for Research on Medical Applications of Psychology, Department of Psychology, University of Cambridge, 5 Salisbury Villas, Station Rd., Cambridge CB1 2JQ, England.

readers were far more frequently at the lower stages of the developmental sequence and far less frequently at the higher stages, compared with average readers matched for nonverbal intelligence score, social class, school, age, and sex. The results of these studies lead one to inquire what aspect or aspects of the reading process are related to the child's performance on axes-of-reference tests. The hypothesis proposed here implicates, as the most obvious candidate, the perception of figure orientation; this ability is necessary in order to recognize certain letters of the alphabet which are distinguished solely through spatial transformations. The high frequency and unusually long persistence of reading errors due to letter reversal, inversion, and rotation are prominent features of certain kinds of reading disability, including dyslexia (Critchley, 1970; Monroe, 1932; Schonell, 1948). It is postulated that in the absence of visual context the perceptual system must be characterized by an intrinsic two-dimensional frame of reference in order to recognize figure orientation. Although this assertion is in the nature of a truism, it has apparently not been previously recognized, either explicitly or implicitly, in theories of orientation perception. However, Rock (1966) reached a similar conclusion in his analysis of perceptual adaptation to a disoriented retinal image, while Fellows (1968) and Gibson and Robinson (1935) came close to recognizing the principle involved, although they did not speculate about the nature or origin of the frame of reference.

Once it has been acknowledged that an egocentric frame of reference is necessary for the perception of figure orientation, it becomes apparent that other variations in behavior, perception, and language often associated with dyslexia result from the absence of the same fundamental structure. In the order of their discussion in this paper, these phenomena are (1) form recognition of all classes of mono-oriented objects which is independent of the figure's egocentric orientation, (2) defective visual sequential scanning, resulting in confused letter and word order, (3) poor visual balance performance, (4) failure to acquire nonspatial ordering relations, including temporal relations and tenses, and (5) the characteristic intellectual profile of severely retarded readers, namely, PIQ/VIQ greater than 1, where PIQ is the performance IQ score and VIQ the verbal IQ score on the WISC. The latter phenomenon is dependent on (1) and (4) above. The association of reading disability with each of these factors has already been established either experimentally or through clinical observation. If the analysis is correct, the possibility then arises that the factors are associated in the individual dyslexic and that there is a subgroup of dyslexics characterized by this symptom complex. This prediction remains to be verified.

THE PERCEPTION OF FIGURE ORIENTATION

Basic Definitions

Bingham (1914) distinguished between the *form* and the *shape* of a figure. He defined the form of a figure in terms of the internal spatial relations of its parts and the shape of a figure according to its relationship with the context. The same convention is adopted in this paper, with the shape of a figure being further distinguished. The *contextual shape* refers to the shape as defined above, and the *egocentric shape* refers to the relation of the figure to the observer. If the observer is upright in the environment, then the contextual shape and the egocentric shape are identical, since the reference for the former—the environmental upright—coincides with the reference for the latter—the egocentric upright. Where shape is used without a qualifying adjective, the egocentric shape is to be understood.

The terms *simultaneous discrimination*, *successive discrimination*, *recognition*, and *identification* are in accord with the definitions specified by Gibson (1969). In what follows, successive discrimination will be abbreviated to *discrimination*. In the context of the perception of orientation and the perception of order, what is said with reference to any one of the tasks of discrimination, recognition, or identification is true of the other two, but not necessarily true of simultaneous discrimination. The reason for this distinction will become clear subsequently.

Some Theories Concerning the Perception of Figure Orientation

The theories reviewed in this section and also the one to be presented in the next are all concerned with the orientation of two-dimensional figures.

Apparently, Mach's (1959) study of the perception of orientation was partly prompted by his observation that children frequently confuse the mirror image pair *b* and *d* and also the pair *p* and *q*. His explanation for this confusion was based on the supposed similarity of "space sensations" associated with eye movements which are symmetrical about the median plane. Presumably, Mach assumed that kinesthetic sensations are associated with eye movements, but it is now known that the position sense of the eye does not depend on proprioception (Brindley and Merton, 1960). According to Mach, the resolution of the aforementioned perceptual confusion depends on the development of laterality. He proposed that eye movement proprioception comes to be associated with haptic sensations from the writing hand in such a way that the afferent signal resulting from an eye movement to the dominant side is endowed with a different value from that of the signal produced by a

symmetrical movement to the contralateral side. While Mach recognized an important principle concerning orientation perception, namely, the necessity for bilateral asymmetry in the organism, it is not likely that this principle is embodied in the kind of mechanism which he suggests. There is not sufficient space in this review to carry out a detailed examination of the eye movement theory of perception. However, it is quite simple to demonstrate that eye movements are not necessary for the perception of spatial location. If reversible and invertible letters are viewed under tachistoscopic conditions, recognition is possible even when the presentation time is short enough to preclude the occurrence of eye movements.

Notwithstanding the above conclusion, it may be prudent to allow, as Sutherland does, that the individual can resort to more than one kind of mechanism. If one of these mechanisms does rely on eye movements, the question arises as to whether such movements are sufficient for shape recognition. Now, in the absence of evidence to the contrary, it may be assumed that, like most people, the dyslexic can from an early age fixate any desired object in the field of view, even though he may not be able to construe its direction as leftward or rightward. This faculty is an illustration of a more general phenomenon, namely, that a subsystem of the nervous system may operate in accordance with certain principles without these concepts necessarily registering in the consciousness of the individual. How this particular mechanism works is well described in Linksz' (1952) functional account of the oculomotor system. Thus even though dyslexics are like everyone else insofar as their ability to execute voluntary eye movements is concerned, this faculty does not insure that they are able to discriminate mirror image shapes. In conclusion, it would appear that the role of eye movements in the perception of orientation is of minimal importance.

Mach's formulation of the problem also requires him to adopt an untenable position *vis-à-vis* the vertical dimension. He maintains that the inherent vertical asymmetry of the oculomotor system accounts for the fact that children have no difficulty discriminating the mirror image pair *b* and *p* or the pair *d* and *q*. Since most children do confuse the members of these pairs at some stage, it would appear that Mach's contention is a prediction from the theory rather than the result of his observations.

Following his observations of some cases of reading disability, Orton (1925, 1928, 1937) described certain features which he believed characterized the group as a whole. Among the phenomena he noted were (1) the tendency to make reversal errors, both in the recognition of individual letters and in the order of letters in words, and (2) delayed or incomplete establishment of cerebral dominance, left-handedness, ambidexterity, or crossed laterality.

The theory proposed by Orton is similar to that of Mach in that they

both involve the concept of dominance or laterality. However, the way in which it is implicated is slightly different in the two theories. Orton based his theory on the observation that the brain contains right and left visual areas which are identical except for their orientation. He also mistakenly assumed that a single stimulus could give rise to an engram (trace) in each hemisphere, the two engrams being in left-right mirror image relationship to each other. Orton believed that the possible existence of the two mirror image traces is responsible for a child's confusion. He further proposed that as a result of the establishment of dominance the engram in the nondominant hemisphere would be suppressed, thus removing the source of the confusion. But when the child is subsequently presented with the mirror image of the first stimulus, mirror image excitation is set up in the dominant hemicortex. Orton does not address himself to the question of how these mirror image engrams in the dominant hemisphere are discriminated. Presumably, he took it for granted, thus begging the question.

As was intimated above, the existence of the cortical engrams in the form postulated by Orton is questionable in view of the organization of the optic pathways within the two hemispheres. Different parts of the stimulus are projected to the two hemispheres depending on the point fixated. If an arrow with its head to the right is fixated at the center, the head is projected into the left hemisphere and the tail into the right hemisphere. In order to project the whole of the stimulus into one hemisphere, the point of fixation would have to be to the right of the head or to the left of the tail. In neither case would any part of the arrow be projected into the other hemisphere. Nor are the projections of the stimulus formed by fixation to the right of the head and to the left of the tail in mirror image relation to each other. Orton might have maintained that the corpus callosum transfers the appropriate part of each projection to the other hemisphere. However, it is unlikely that the brain provides pathways which route stimuli to locations where they would or should be suppressed. A further objection to Orton's theory is that it deals only with the discrimination of left-right mirror image shapes, disregarding the question of up-down mirror images and 180° rotations.

The theories due to Sutherland, Deutsch, and Dodwell are not complete theories of form and shape discrimination, as the authors themselves recognize. Rather, what all three propose are mechanisms which carry out the initial processing of perceptual information. It therefore remains for the outputs of their mechanisms to be detected, discriminated, and categorized. Generally, what is called for in the ancillary systems is a simpler kind of discrimination such as that between different levels of excitation, a process which the authors believe, perhaps with some justification, to be fairly easily realizable. But in view of their incomplete nature, the models proposed are

susceptible to one weakness in particular. That is, they may not actually discriminate the parameter concerned but merely produce an output which, although different in detail, varies along the same dimension as the input. In other words, it is necessary to examine carefully whether the mechanisms proposed embody the logical principle underlying the perception of orientation.

While all three mechanisms are designed to discriminate form as well as shape, attention will be focused, in this review, solely on their performance *vis-à-vis* the latter parameter. (Incidentally, in formulating their theories none of the three authors makes an explicit distinction between form and shape.) It should also be pointed out that the three models were designed to account for the discriminatory behavior of primitive organisms such as the octopus and rat, not that of the human subject. How successful they are will be judged in relation to the experimental findings which the authors themselves refer to. The latter data are not without interest in the present context because there are certain similarities between the performance of the child and that of the octopus and rat. A detailed description of the three models is outside the scope of this review, the main purpose of which is to draw attention to the fact that the mechanisms are not completely successful in incorporating the required principle.

Sutherland (1957*a,b*, 1958, 1959, 1960*a,b,c*, 1961, 1963*a,b*) produced two variants of his "stimulus analyzing mechanism," both being designed to account for some findings concerning the perception of form and shape in the octopus. The first relied on hypothetical physiological processes such as "projection" and "counting" (the summation of excitation by means of a scanning process). Sutherland envisaged that in the octopus's visual system shapes are converted into their horizontal and vertical projections. The shape concerned falls on an array of receptors which are arranged in rows and columns. These receptor cells are connected both within rows and within columns in order that the cell outputs may be summed vertically and horizontally. It remains to decide whether the mechanism uses a vertical, horizontal, or composite projection.

Sutherland exhibits some confusion about the convention underlying the terms "horizontal" and "vertical projection." In an early paper (Sutherland, 1959), the terms are in accord with the usual convention, namely, that the pertinent axis is the one onto which the projection is made, not the direction of "counting" or "scanning" which produces this projection. However, in subsequent papers Sutherland employs the opposite definitions. This departure would not be of much consequence except that it results in some confusion in the later correspondence with Deutsch (1960*b*). In order to avoid the same confusion it should be noted that the usual convention is adopted in this

paper and that in one of the quotations below Sutherland is using the opposite terminology.

Returning to the question of whether a vertical, horizontal, or composite projection is used, the implications of each of these processes may be examined in relation to the octopus's performance on a mirror image discrimination task. Sutherland (1960a) found that the octopus can discriminate both up-down and left-right mirror images, with the latter relationship presenting greater difficulties than the former. If a vertical projection is used, then the mechanism produces different outputs in the case of up-down mirror images and identical outputs in the case of left-right mirror images. The converse is true if a horizontal projection is used. If a composite projection is employed, then the mechanism discriminates equally between up-down and between left-right mirror images. Yet none of these three outcomes accords with the octopus's actual behavior. Referring to this deficiency, Sutherland (1963a) states: "To explain the early evidence it was necessary to make the further assumption that behavior is more readily determined by differences in the horizontal projections of shapes than by differences in their vertical projections" (p. 118). But this statement is not an assumption adopted to explain the evidence; it is a restatement of the evidence itself. Sutherland does not suggest how the interaxis inhomogeneity could be embodied in his mechanism. In any case, if the input stimuli are (say) a T-form and its up-down mirror image, and assuming that vertical projection applies, then the respective outputs are an L-form and its left-right mirror image (Sutherland, 1957a, Fig. 2). It thus remains for an ancillary mechanism at the output to discriminate orientation. It does not matter whether the output signals are spatially or temporally distributed: Sutherland has begged the question, at least insofar as the perception of orientation is concerned.

Furthermore, even if it is assumed that there is an appropriate device at its output, it is difficult to see how the mechanism is able to account for the fact that the octopus can, with difficulty, learn to discriminate mirror image oblique rectangles. Sutherland (1957b) believes that "it would be possible to perform this discrimination on the systems proposed if the octopus first learned to fixate a given part of the figure" (p. 68). Yet his theoretical formulation and experimental procedure have, up to this point, been based on the assumption that the octopus sees the figure as a whole (Sutherland, 1957a), so that it should be of no consequence where the animal is fixating. The reason that the mechanism fails when it comes to the discrimination of mirror image obliques is that Sutherland has neglected information which is, in principle, available from the scanning process. Space does not allow elaboration of this point.

Following the publication of Hubel and Wiesel's (1959, 1962) findings

concerning the electrophysiology of the cat's visual cortex, the mechanism was modified in order to incorporate elements which resembled receptive fields. Unfortunately, such fields can only detect direction, not polarity. Consequently, the mechanism, as Sutherland (1963*a*) recognized, could no longer discriminate between either up-down or left-right mirror images, whether the form concerned is biaxially symmetrical (e.g., a rectangle) or bilaterally symmetrical (e.g., a T-form).

In principle, Deutsch's (1960*a,b*) mechanism samples the height of the shape at intervals along the horizontal dimension, the magnitude of each sample being inversely proportional to the height of the shape at the point in question. The samples are then integrated over the horizontal extent, producing an output which varies along one dimension, namely, that of level or magnitude of "neural activity." It is not possible to speculate about the nature of the octopus's perceptual world, but if a similar scheme is envisaged for the human visual system, the major objection would be that it is inconceivable that the output of this kind of mechanism could impart to a form its phenomenal appearance. Even though the mechanism is successful in discriminating certain forms, it is quite likely that two figures could be designed with different forms but nevertheless produce identical outputs.

The purpose of Deutsch's model was to explain the octopus's discriminatory behavior, the components of the mechanism being suggested by certain neurohistological features of the animal's plexiform zone. He referred to Sutherland's experimental findings concerning form and shape discrimination in the octopus, but, at least as far as the perception of orientation is concerned, he did not pay very careful attention to what Sutherland actually found. Thus Deutsch (1960*a*) states that, according to Sutherland, mirror image oblique rectangles and also left-right mirror images of bilaterally symmetrical forms are indiscriminable. What Sutherland actually found was that the octopus could discriminate these shapes, but only with difficulty. Presumably, it would be possible to modify the model and reinterpret the neurohistology, but this kind of adjustment would tend to negate the value of such exercises. In any event, the feature of Deutsch's model which enabled it to discriminate between up-down mirror images was not derived from the neural structure but was an accessory assumption. The formulation of this assumption (Deutsch, 1960*a*) amounts to little more than a restatement of the problem and adds nothing to our understanding of how mirror images are discriminated.

Dodwell's (1957*a,b*, 1961) model attempted to account for six characteristics of form and shape recognition in primitive visual systems such as that of the rat. Similar characteristics had been enumerated originally by Deutsch (1955), but Dodwell (1957*b*) revised two of them. One revision concerned the

recognition of forms in different orientations: while Deutsch believed that rotation constancy did apply, Dodwell dissented from this view. But as a result of this revision two of the six features which Dodwell took account of were contradictory. One was the finding that primitive visual systems are apparently not capable of recognizing a form in any orientation, and the other was that they are unable to tell the difference between mirror image shapes. Dodwell evidently did not realize that if the figure in question is bilaterally symmetrical then the mirror image is a special case of rotation. Even so, the operation of his mechanism is in accordance with these conflicting requirements. Thus it does not discriminate between up-down or left-right mirror images whether the form concerned is bilaterally symmetrical or biaxially symmetrical. While this feature conforms to Dodwell's stated requirements, it appears to conflict with the experimental evidence concerning the perception of orientation in rats. In fact, Dodwell refers to the paper by Lashley (1938) in which it was reported that this animal *could* discriminate both up-down and left-right mirror images.

A detailed description of Dodwell's model is outside the scope of this review. Briefly, an array of receptors arranged along vertical and horizontal coordinates generates an output consisting of one or more pulses. According to the shape presented, the pulses vary in both magnitude and temporal pattern, and either of these parameters is sufficient to discriminate between shapes. On the other hand, neither of the parameters conveys any information about the spatial polarity of the shape. In the light of his findings from experiments with the octopus, Sutherland (1960*b*) criticized Dodwell's model for its failure to discriminate between mirror image shapes. Dodwell, in reply, questioned Sutherland's experimental findings, but in doing so denied the very basis for the difference between mirror image shapes. He maintained that Sutherland's use of solid figures (*U*'s), rather than contours, invalidated the findings because although the up-down mirror images, for example, had equal luminance-area products, the distribution of luminance was different in each case. Dodwell (1961), referring to a figure showing an upright (*f*) and an inverted (*g*) U-form, writes: "Thus this pair could be discriminated on the basis of 'brighter above' (*g*) versus 'brighter below' (*f*)" (p. 579). But these mirror images, whether solid or contour, are distinguished by virtue of no other feature.

Summarizing the shortcomings of the foregoing theories of Sutherland, Deutsch, and Dodwell, a criticism which applies to all three is their failure to distinguish between the form and the shape of a figure. Both Deutsch and Dodwell misrepresent the experimental evidence then available to them, rendering it unnecessary for them to account for the discrimination of up-down mirror images (Dodwell) or left-right mirror images (Deutsch and

Dodwell). Neither Deutsch nor Sutherland explicitly formulates the principle underlying the perception of orientation (Dodwell had no need to). Nor do these two authors throw any light on the mechanism of orientation perception: in Deutsch's theory it is provided for by an "accessory assumption," and in Sutherland's model it remains for an ancillary mechanism to carry out a polarity discrimination.

Gibson *et al.* (1963b) and Gibson (1969) have proposed a list of distinctive features for the upper-case alphabet. Before examining this theory, it should be pointed out that a theory of orientation perception could be compatible with a number of theories of *form* perception. In particular, the theory to be presented in the next section is compatible with the distinctive-features theory of form perception. Emphasis has been given to the word *form* in order to convey that the features selected for the list should, *a priori*, be rotation invariant, e.g., open/closed, straight/curve, but not vertical line/horizontal line. If such features are not selected, there is no conceivable basis for describing the phenomenon of rotation constancy, whether the individual concerned is dyslexic or not. By the same token, it has to be recognized that *b, d, p*, and *q*, for example, have something in common, their form, before the individual can possess a properly constituted conception of how they differ in orientation.

The feature list compiled by Gibson *et al.* does not restrict the members to those which are, strictly speaking, properties of the form of the figure but, for example, specifies a feature called "discontinuity" (with subcategories "vertical" and "horizontal") which varies according to the relation of the figure to the observer. "Discontinuity" varies according to orientation because Gibson (1969) "assumes a scanning process which proceeds vertically downward or horizontally from left to right. Discontinuity would result if a line that is being scanned terminates" (p. 89). There are two objections to this feature and the rationale for its existence. In the first place, notwithstanding the word "or" in the above quotation, two scanning processes are required, one to detect the vertical discontinuities and the other to detect the horizontal discontinuities. Presumably, such a system could not detect diagonal discontinuities, yet in Gibson's (1969) scheme the letter A is said to have vertical discontinuities. Second, while Gibson's scheme would enable *p* to be distinguished from *b* or *d*, it makes no distinction between *p* and *q* or between *b* and *d*. The lesson from this evaluation of Gibson's theory is that the features selected should be a function of just the form of the letter; they should apply whatever the orientation of the letter with respect to the observer. (Brown, 1963, has made the same observation.) A list of "shape features" may then be added to the form features in order to distinguish letters with the same form. The "shape features" are specified by putting a

certain form feature (the discontinuity, say) in a prescribed relation to the Cartesian frame of reference (in the second quadrant, in the case of *b*). Here, the term *discontinuity* refers to a purely topological property of the form; it applies whatever the orientation of the letter.

Hoffman (1966, 1967) formulated the perceptual constancies relating to form in terms of Lie groups of transformations and interpreted letter reversals in the light of this analysis. His interpretation implicates a binocular function-shape-slant invariance—in what is almost certainly a monocular process. Moreover, the analysis does not contain any reference to the basic underlying principle. Hoffman (1967) writes: “The picture is thus—almost by definition—one of the failure of shape, or form, constancy, in particular of that component of shape constancy involving rotation invariance (orientation constancy)” (Appendix 3, p. 2). Yet unless rotation constancy applies, the individual cannot tell that *b*, *d*, *p*, and *q* have something in common, namely, their form, and before this stage of development occurs he cannot have a properly constituted conception of how they differ in orientation. There is an alternative possibility: form constancy may not apply but the individual may still be able to discriminate shape. However, this situation does not accord with what is usually understood by the perception of orientation and may characterize an earlier stage of development prior to the establishment of rotation constancy (Lashley, 1938). Indeed, the failure of rotation constancy referred to by Hoffman would imply a regression to this earlier stage of development in which shape discrimination is, almost by definition, guaranteed. It is therefore necessary to go beyond the postulation of rotation constancy, and in doing so the deficiency in Hoffman’s analysis becomes apparent.

In Hoffman’s theory, transformations are defined with respect to the x,y coordinate system. For example, if a form is rotation invariant, it is invariant with respect to the transformation: $x' = x \cos t - y \sin t$, $y' = x \sin t + y \cos t$. It is not possible to deduce from this statement whether the subject has knowledge of the angular relation between the point set (x,y) and the point set (x',y') . In order to be able to specify whether he has such knowledge, it is necessary to assume the psychological reality of the Cartesian reference system with respect to which (x,y) and (x',y') are defined. Hoffman does not postulate a psychological counterpart of the Cartesian frame which is implicit in his mathematical formulation.

A Statement of the Hypothesis

The principle involved in the perception of orientation may be quite simply stated. Basically, the difference between reversible, invertible, and

rotatable letters, such as *b*, *d*, *p*, and *q*, resides in the relation of the form to the subject's body. Now it is fairly obvious that the mature reader, in identifying one of these letters, does not, by a process of conscious visual analysis, relate the features of the letter to parts of his own (visually observed) body. Nor does he appeal to an extracorporeal reference in the visual context of the letter. But since it is logically necessary to invoke a reference system in order to determine whether the shape in question is a *b*, *d*, *p*, or *q*, it must be concluded that the visual-perceptual system, in the mature reader, functions as if it is endowed with an intrinsic, egocentric, two-dimensional frame of reference. (In what follows, an egocentric reference frame always refers to one that is intrinsic to the visual system, that is, not given by virtue of the relation of objects within the visual field.) The axes of the egocentric reference frame each comprise two components, namely, (1) a direction (vertical or horizontal) and (2) a polarity (up-down or left-right). Having specified the distinctive features which are common to the form of a set of transformable letters, then, as was proposed in the previous section, the members of the set are distinguished by putting a particular feature in a prescribed relation to the Cartesian frame of reference. This is the logical structure, but there must be a psychological counterpart which resembles it and includes the logical features. One of the special characteristics of the psychological structure is that the frame of reference is freely movable in the field of view, or at least within that neighborhood of the fixation point in which form recognition is possible. The structure is also characterized by both inter- and intra-axis inhomogeneity. The interaxis inhomogeneity applies at the perceptual level, when the frame of reference is developing, and is reflected in the fact that left-right letter reversals are more frequent than up-down reversals. The intra-axis inhomogeneity applies mainly at the cognitive level, and this feature will become apparent in what follows.

It may be mentioned at this point that the contemporaneous influences of eye movements, the tactile-kinesthetic sense, and the force of gravity on the body are believed to be of no fundamental significance as far as the visual perception of figure orientation is concerned. Furthermore, analysis of investigations concerning perceptual adaptation (Rock, 1966) suggests that none of the above factors provides the veridical reference for figure orientation during the ontogenesis of the visual system.

Notwithstanding the above remarks concerning the contextual reference, it is possible that a child whose egocentric frame of reference had not yet developed could use either the visual body scheme reference or an extracorporeal reference. Indeed, some training techniques (Newson, 1955) have included devices which provide a contextual reference for the child; naturally, their use has to be supervised. Thus while it is not necessary for the reference

frame to be one intrinsic to the visual system, it is clear that the immediate and efficient identification of figure orientation depends on the inherent nature of this structure.

Rock (1966) considered the question of adaptation to a disoriented image and argued that the intrinsic reference is provided by virtue of a particular property of the memory trace, namely, that it is orientation-specific. According to his theory, when memory traces are laid down they are faithful to the egocentric orientation of the stimulus figure. Rock refers to this property as the stimulus-copy aspect of a memory trace, and it is a necessary but not sufficient condition for the establishment of an intrinsic egocentric frame of reference. Other properties of the proximal stimulus, such as straight/curve, are also represented in the memory trace by a stimulus-copy aspect, but when the latter term appears in this paper it is the parameter of orientation that is being referred to. Corresponding to these absolute attributes of the memory trace are phenomenal qualities which are also stored in memory (the representational aspect of the trace), and the former traces become "signs of" phenomenal features which are associated with them. Insofar as the use of the above terms is concerned, the present analysis is consistent with Rock's view, although, as will become apparent, it departs from his formulation in one respect.

Now the stimulus-copy aspect of the memory trace would not be of much use if visual experience were restricted to reversible and invertible letters because, when taken as a whole, the set of traces corresponding to the quartet *b*, *d*, *p*, and *q*, for example, is characterized by biaxial symmetry, whereas what is required of the Cartesian frame is biaxial asymmetry. However, considering the world of nongraphic visual experience and the fact that the constraint of gravity leads, throughout the greater part of the developmental period, to an effectively unique, biaxial, spatial relationship between perceiver and perceived, and coupling this with the vertically asymmetrical nature of the visual world and the orientation-specific character of memory traces, then it is clear that the latter can provide the basis for the vertical dimension of the reference frame. It is not suggested that when a letter is observed it is perceived against an imaginary background of earth and sky. Rather, the intrinsic vertical axis must be a feature abstracted from the complex of memory traces which correspond to mono-oriented, vertically asymmetrical, natural objects. In addition, it must be assumed that the process of abstraction does not lead to the identity of the members of the trace complex being obliterated. How the Cartesian frame manifests itself phenomenally will be described at a later stage.

It should perhaps be emphasized that the orientation-specific nature of memory traces does not, by itself, enable reversible and invertible letters to be

distinguished. It merely guarantees that, corresponding to a given orientation of the stimulus figure, there is a unique orientation for its memory trace. It does not follow that the subject has knowledge of the absolute orientation of this trace relative to his own body. Similarly, the relative orientation between the stimuli *b* and *q*, for example, has a unique counterpart in the angular relation between the corresponding memory traces. In this instance, assuming the letters are presented simultaneously, the subject *could* judge their relative angular separation phenomenally, but this capability would only enable him to tell that the pair *b d*, taken together, is different from the pair *b q*; it would not be sufficient to facilitate recognition or identification of the members of the pair. So, if the memory store contains no traces other than those corresponding to the quartet *b, d, p, and q*, and one attempts to identify which is which just on the basis of orientation-specificity, a circular argument results. For although it could be said that, phenomenally, *b* is judged by its relation to *q*, for example, this is not legitimate because it assumes that the *q* has already been identified as such, whereas, since no special status can be assumed for it among the four, the *q* can only be defined in the same way as the *b*. Of course, an outside observer can, in theory, determine the absolute relation of the *b*-trace to the subject's body and in this way identify it, but as was pointed out above this information is not available to the subject himself. It is thus necessary to postulate a framework analogous to the one which is available to the outside observer but present in the subject's perceptual world. The establishment of the frame of reference depends not only on the orientation-specific nature of memory traces but also on an environment which contains *mono-oriented*, vertically (and horizontally) asymmetrical objects; it is the traces of such objects which endow the frame of reference with its requisite polarity.

So far, the discussion has centered around the origin of the frame's vertical axis, but when it comes to the horizontal axis the situation is slightly different. The structure of the everyday visual environment possesses the component of horizontal direction but not that of left-right polarity (ignoring graphic material for the moment). Now, as discussed previously, it is conceivable that the child could appeal either to a reference on his own body (a mole on one hand, say) or to one in the extracorporeal visual context, but these are very faint and transitory references. It is far more likely, and in view of the postulated stimulus-copy aspect of memory traces it is difficult to avoid concluding, that the reference for the horizontal polarity is derived from the graphic material itself. In particular, it would be derived from those letters, such as *c* and *e*, which are not related to each other through spatial transformations, since their memory traces provide an unambiguous and systematic left-right polarization of the complex. As in the case of the vertical

axis, the polarity of the frame would be a feature abstracted from the complex of orientation-specific memory traces. Since the child stands and walks (in a vertically asymmetrical world) several years before he meets (horizontally asymmetrical) graphic material, the polarity of the horizontal axis does not become established until some time after that of the vertical axis, with the result that letter reversals are more frequent, and persist longer, than inversions.

Since dyslexics are exposed to the same biaxially asymmetrical world as other people and do not generally exhibit a gross defect in form perception, at least as far as natural objects are concerned, their lack of a Cartesian frame could be attributed to one of two conditions: either (1) a mono-oriented figure gives rise to memory traces whose orientations vary randomly from one instance of the figure to the next, or (2) if a stimulus-copy aspect of the trace is recorded, then the process whereby the structure of the trace complex is abstracted is faulty or absent. In order to make explicit what is involved in alternative (1), consider first of all, the situation obtaining in normal individuals. The assumption that the memory trace has a stimulus-copy aspect implies that its orientation, θ_t , is some function, F , of the orientation, θ_s , of the stimulus figure. (The specification of θ_s and θ_t presupposes that an outside observer can use a frame of reference which is common to both the stimulus situation and the trace complex.) Although F need not be linear, it is simplest to assume, for the purpose of illustration, that $\theta_t = \theta_s + C$, where C is a constant. But if trace orientation and stimulus orientation are independent of each other in the dyslexic, it would mean that the function F is a random variable. For example, the density function of F might be given by $p(F) = p(\theta_t) = \frac{1}{2\pi}$, $0 < \theta_t < 2\pi$, the uniform density function being one that does not result in a polarized trace complex. It is difficult to envisage how situation (1) could arise, given the specificity of neural connection which is presumably a feature of the histology of both dyslexic and normal individuals, so one concludes that alternative (2) is the more likely of the two.

Although, for the purposes of the foregoing analysis, it has been necessary to treat the two variables *form* and *orientation* independently, this distinction does not convey how these attributes are perceived phenomenally. On the one hand, the recognition of a form, especially a complex one, depends on its orientation and, on the other, the judgment of figure orientation presupposes, *ipso facto*, that the form or at least the class to which it belongs has been recognized. While a form may be recognized for what it is in any aspect, the way its orientation is judged is through changes in phenomenal form which accompany rotation of the figure, and this reasoning applies whether the figure belongs to the class of natural objects or to that of graphic material.

The change in phenomenal form with orientation may be illustrated by reference to a specific figure, namely, the square. In order to rule out the influence of any contextual reference, suppose that the subject views the square either in a supine position, with the figure in a horizontal plane above, or bent forward with the figure situated on the floor. If two sides of the square are aligned with his egocentric top-bottom axis, then the figure appears phenomenally square. But if it is tilted 45° to either side, it takes on a quite different phenomenal form, and is usually referred to as "diamond-shaped." At the same time, the form of the figure is still recognized to be a square. If a more complex figure, such as a face, is inverted, the change in phenomenal form is so drastic that it becomes very difficult to identify the individual. One concludes that the change in phenomenal form which accompanies rotation of an isolated figure viewed against a homogeneous background is due to the covert influence of those memory traces which constitute the egocentric Cartesian frame. It is possible to manipulate the components of the Cartesian frame experimentally and thus demonstrate its influence on phenomenal form, by wearing a device which rotates the visual field. Rock and others have argued that when perceptual adaptation takes place in these circumstances it effectively involves the displacement of the egocentric frame, that is, the replacement of old traces by new ones in a different orientation. Since this process of adaptation results in a scene which was originally tilted becoming phenomenally upright, it would, if the rotation produced by the device is 45° , presumably result in an isolated diamond shape becoming phenomenally square.

An indication of the influence of the egocentric frame on phenomenal form may also be obtained by drawing an analogy with the situation in which a form is judged in relation to a *contextual* reference. Figures 1 and 2, taken from Kopfermann (1930), illustrate the effect of a contextual reference on the phenomenal form of a diamond and square, respectively. In Figure 1B, where the contextual reference provided by the outer rectangle is aligned with both the egocentric frame and the frame provided by the page, the inner form is phenomenally a diamond. But when the immediate framework is tilted, as in Fig. 1A, the influence of the other two frames is to a certain extent overcome, and although the situation is phenomenally more ambiguous than in Fig. 1B the figure previously judged as a diamond has, in Fig. 1A, a tendency to take on the appearance of a square. The converse situation is illustrated in Fig. 2. In either case, if the contextual reference (the rectangle) is removed the same two phenomenal forms are seen when the principal directions of the egocentric frame are aligned with the directions which the contextual frame would have occupied had it not been removed. This effect is best observed with the figure lying in a horizontal plane so as to remove the

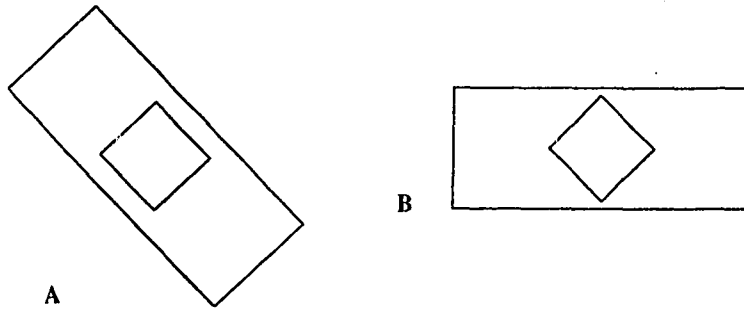


Fig. 1. Diamond with contextual frame.

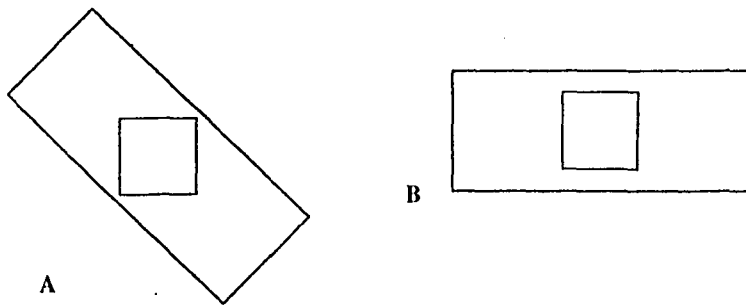


Fig. 2. Square with contextual frame.

influence of the wider contextual framework. Otherwise, if the figure is lying in a vertical plane and its context has strong directional components, then the latter primarily determine the phenomenal form and the effect of the egocentric frame is overwhelmed.

When it comes to examining the foregoing hypothesis in relation to the developmental sequence of Piaget and Inhelder (1956) concerning axes of reference, it appears that their formulation is deficient in two respects. First of all, the final stage of the sequence, stage IIIB, demonstrates only that the child can construct parallels provided that the pertinent directions are given in the visual environment. It does not follow that he can also orient a line in a prescribed egocentric direction in the absence of visual contextual cues. Rock (1954, 1966) has devised an experiment which is a very pure test of this ability. As far as is known, the experiment has not been performed with young subjects to determine the age at which the ability is first acquired. However, it seems reasonable to suppose that a child passes through Piaget

and Inhelder's stage IIIB before he is able to recognize a line's egocentric orientation; the latter level of development may therefore be provisionally termed stage IV.

In Rock's experiment, the subject lying on his back in a completely dark room observes a luminous line, which can be rotated in a horizontal plane. The line is advanced in (say) 5° intervals, and the subject is required to specify when it is in the egocentric top-bottom or left-right direction. If carried out with young subjects or those suspected of being dyslexic, the format and instructions used by Rock in his experiment would require a certain amount of modification.

The other respect in which Piaget and Inhelder's conception of a frame of reference is deficient (as far as the hypothesis of this paper is concerned) is that it ignores the polarity of the two axes. That is, the experiments proposed by the authors in their chapter on "Systems of Reference and Horizontal-Vertical Co-ordinates" do not allow the child to demonstrate his grasp of the notion of polarity, although they refer to "up-down" and "left-right" at various points in this chapter. However, Piaget (1928) has dealt with the child's conception of left-right elsewhere, and the developmental stages were confirmed by Elkind (1961). A similar sequence probably applies in the case of the up-down relation, but with each stage occurring somewhat earlier. The Piagetian sequences referred to here do not appear to have been integrated, and it may not be appropriate to do so because the former one (concerning the conception of direction) was defined partly on the basis of what are essentially discrimination tasks, while the experiments used to elucidate the child's conception of polarity have more in common with an identification task.

Earlier, when discussing the perceptual system's acquisition of left-right polarity, it was implied that the ability to identify the right and left sides of the body may not be necessary in order to recognize left-right mirror images. Furthermore, in the absence of the visual system's capacity to establish a frame of reference, identification of left and right would not be sufficient for instantaneous recognition of such shapes, although it could facilitate this task at an "analytical" level. Now, it is possible to bypass the question of the verbal identification of left and right sides (or top and bottom, for that matter) and still determine whether the subject's visual system is endowed with the necessary basis for the recognition of polarity. This again involves a modification of an experiment devised by Rock (1966). Subjects with heads bent forward viewed two luminous dots located on the floor below them. The room was otherwise dark. One of the dots rotated about the other, and the subjects were required to identify the 12 o'clock position of the rotating dot. As before, the instructions given to young subjects would have to be modified because they would not necessarily be expected to know what was meant by

12 o'clock, especially if they were dyslexic. Basically, the modification would involve devising a recognition task rather than using an identification task. For example, if the position of the rotating dot were put under the control of the subject, he would be asked to reproduce a position of the dot which had been previously demonstrated by the experimenter.

It was argued above that the subject's ability to verbally identify his left and right sides does not in any way facilitate the process by which the Cartesian frame is established. On the contrary, and this is a thesis to be developed in a later section, it is more likely that the semantic differentiation of certain polar opposites denoting spatial position (of which *left-right* are examples) and also of some antonymous pairs of nonspatial adjectives and adverbs depends on the establishment of a perceptual frame of reference. At first sight, this idea appears to be in conflict with the observation that children generally learn to tell left from right about 3 years before they cease making reversal errors. An attempt to resolve this apparent contradiction is made in a later section, where it is suggested that the semantic differentiation of *up* and *down* (and also *left* and *right*) follows the establishment of an inchoate frame of reference which develops between 4 and 6 years of age, while the recognition of invertible and reversible letters depends on the fully elaborated Cartesian frame which does not become established until about 9 years.

The hypothesis outlined above, with its various ramifications, remains to be verified experimentally. In particular, there is no evidence so far to show that the child's level of development, as designated by his performance on the supplemented version of Piaget and Inhelder's tests concerning axes of reference, is related to the perception of orientation rather than some other aspect of reading ability. Should evidence supporting the hypothesis be obtained, there would still remain the problem of explaining why children who make more reversal errors than usual and persist in doing so experience so much difficulty with reading in general. Assuming their *form* recognition is intact, dyslexics should be able to recognize words at the whole-word level, even though their shape recognition is faulty. For when a word is inverted, reversed, or rotated (i.e., reversed or rotated as a whole, not letter by letter), its form is preserved, and only in the case of very few words does this kind of transformation lead to a shape representing another word with which the original could be confused. (An example is *bob*, which becomes *pop* when inverted.) Thus the difficulty experienced by retarded readers cannot result solely from a defect in shape recognition. Nor does this difficulty, in the majority of cases, result from a gross defect in form discrimination. The primary characteristic of the deficit appears to be the limited capacity of form memory, at least as far as graphic material is concerned. A possible explanation for this defect will be offered in the section on "Visual Sequential Scanning."

THE CARTESIAN FRAME OF REFERENCE: A STRUCTURAL BASIS FOR SOME FURTHER ASPECTS OF BEHAVIOR, PERCEPTION, AND LANGUAGE

The concept of a Cartesian frame of reference, as well as being the basis for the perception of figure orientation, has further consequences for the recognition of form within the visual mode. The influence of this concept also spreads downward, to use a neurological term, to the level of behavioral reflexes and upward to the semantic level.

Form Recognition as a Function of Figure Orientation

What is of interest here is not the recognition or identification of the orientation of a figure but the change in phenomenal form of an object, whether graphic or nongraphic, as its egocentric orientation changes. Many investigators who have worn inverting devices have commented on the changed appearance of objects in the field of view. In particular, text and human faces become almost unrecognizable in this position. Rock (1966) believes that this change in phenomenal form is unrelated to the question of perceived egocentric orientation: "Therefore, the normal vs. strange appearance of shapes is not to be confused with their perceived egocentric orientation. With sufficient experience, familiar objects would undoubtedly cease appearing strange (because, I believe, new traces in the new orientation in the substrate are acquired), but this does not imply a righting of the scene" (p. 64). Rock's point here is that an upside down object could lose its "strangeness" of form and still be recognized as upside down. It is difficult to see the justification for this claim, especially if it refers to an isolated object against a homogeneous background, text, regardless of the background, or the whole visual field. In fact, referring to the latter situation, Rock attributes the disappearance of "strangeness" to the acquisition of new traces in the substrate. Presumably, these new traces are faithful to the egocentric orientation of the stimulus, so that they go toward establishing the new reference for the veridical perception of uprightiness. In other words, it is on the formation of these new traces that Rock would base his contention that a retinally upright image would eventually result in veridically upright perception. Rock's conclusion would be correct if it could be assumed that less reinforcement of the trace is required to eliminate "strangeness" than to establish veridically upright perception. The experiments on perceptual adaptation do not appear to give unequivocal support to this assumption.

As was indicated in the previous section, the situation in the case of an object which has a structured context and a preferred relation to this context

is slightly different. If the contextual orientation of the object changes while the observer remains upright, the change in phenomenal form can result either from the changed egocentric orientation of the object or from the fact that its relation to the context has changed. One of Rock's experiments has separated these two factors and has shown that the change in phenomenal form is due mainly to the changed relation of the object to the context. However, Rock noted that an exception to this rule occurs in the case of graphic material: recognition of this class of objects depends solely on egocentric orientation, and the same applies to human faces.

The remarkable nature of dyslexics' perceptual world is often revealed through their drawings: they have been known to produce faithful life-sized portraits—drawn upside down (Tansley, 1971). Retarded readers' disregard for orientation has also been demonstrated by Lovell *et al.* (1964). On a test of rotation (Shapiro *et al.*, 1962), there was a tendency for backward readers to reproduce abstract designs correctly, but in a different orientation. This finding, that many dyslexics' form recognition of all classes of objects appears to be independent of orientation, is probably connected with the lack of an egocentric frame of reference. To establish the connection, it is possible to ask a slightly different question from that which Rock posed, namely, would the same impression of phenomenal form be obtained for all orientations of an object if the Cartesian frame did not become established? Now, it was suggested previously that the frame does not manifest itself through being emblazoned on the visual background, but rather through its covert influence on the phenomenal form of a figure. That is, the phenomenal form of an object varies as a function of its egocentric orientation, and the latter parameter is judged in terms of the former attribute. As was implied in the previous section, the reason that the dyslexic is unable to judge the orientation of a graphic object is because its phenomenal form is rotation invariant. On the other hand, while the change in phenomenal form facilitates the judgment of orientation in the normal individual, there is a further consequence in that it may affect recognition of the form concerned (Gibson and Robinson, 1935; Yin, 1969). But if constancy of phenomenal form applies in the dyslexic, one would infer that he experiences no decrement in form recognition when a mono-oriented object is inverted or otherwise disoriented. In the above discussion, the stimulus situation has been assumed to be one of the following: an isolated object against a homogeneous background, graphic material or human faces, regardless of their context, or the whole field of view. Otherwise, any contextual framework would influence the effects which have been attributed to the egocentric framework.

Thus the conclusion reached here is that letter reversal errors and form recognition of all classes of objects which is independent of figure orientation

are consequences of the same perceptual deficit. It is highly likely, but nevertheless remains to be proven, that it is the lack of an egocentric frame of reference, with the aforementioned consequences for form recognition, that facilitates dyslexics' performance on tasks such as solving jigsaw puzzles. Their performance is enhanced probably because each puzzle piece would present a unique phenomenal form independent of its orientation. The effect of this perceptual deficit on retarded readers' performance on one of the WISC subtests will be discussed in a subsequent section.

Visual Sequential Scanning

During the process of reading, a scanning operation (in conjunction with numerous other faculties) converts the spatially ordered graphic material into temporally ordered inner speech. The term "scanning" is used here to refer not only to the series of saccades executed in traversing a line of print but also the process whereby the letters and words lying within the span of one fixation are sampled. The two processes rely on the same property of the perceptual system, although it might appear that the former process depends on a motor reference. It may be that in the mature reader the directional (horizontal, vertical) and polar (rightward, downward) aspects of the motor process, but not its control, are automatic, i.e., effectively independent of visual perception and memory. But the ontogenesis of the scanning process depends on certain characteristics of the individual's representation of space.

The justification for the above view hinges largely on a functional description of the oculomotor system, such as that produced by Linksz (1952). Among the different types of eye movement which this author distinguishes are what he calls "command movements." Linksz gives as an example of such movements the ability of the subject to move his eyes in response to directions like "up," "down," "left," and "right," even though he may be in the dark or have his eyes closed. It is a single step from this kind of task for the subject to adopt a convention with respect to the scanning process (rightward within lines, downward between lines). Where the hypothesis of this paper would depart from that of Linksz is in specifying the nature of the reference on which the ontogenesis of command movements depends. His formulation implicates proprioceptive memory of the body schema, the efferent control signals being derived from Brodmann area 8 in the frontal lobes. However, it is possible to again appeal to visual memory as the source of the reference if three assumptions are made: (1) memory traces are laid down in an orientation-specific fashion, (2) the polar and directional components of the Cartesian frame can be abstracted from the trace complex, and (3) some process corresponding to the Cartesian frame is set up in an area

of preoccipital cortex which has internuncial connections with the efferent fibers from the occipital cortex to the supranuclear control centers of the oculomotor system. But if eye movements during the process of learning to read are regarded as "voluntary," then the last assumption does not accord with the generally accepted view concerning the origin of efferents serving this type of movement, namely, that they arise in the motor areas of the frontal lobes. However, there are also connections from the preoccipital areas to the frontal lobes, so that assumption (3) is not necessarily in conflict with the general view. Both types of reference (visual and proprioceptive) undoubtedly exist since blind persons can tactually scan braille. The question is whether their tactile-kinesthetic framework would enable them to learn to direct their eyes in a prescribed direction. It seems unlikely that they would be able to do so, since the afferent fibers from the extraocular muscles serve peripheral control purposes and are not integrated with the individual's haptic space (Brindley and Merton, 1960).

In the literature on dyslexia, there is frequent reference to the type of reading error in which the order of letters within a word is reversed or otherwise confused (Critchley, 1970; Money, 1962). Furthermore, a number of investigators have reported a relationship between children's reading ability and the accuracy with which they can match auditory and visual series. Goodnow (1971) refers to many of the latter studies in her paper on the topic of auditory-visual matching. As she points out, performance on the matching task may be determined by a number of factors such as attention and memory as well as the central one of translation from a spatial to a temporal series or *vice versa*. Goodnow and also Kahn and Birch (1968) have carried out experiments to determine whether factors other than the central one mentioned mediate the relationship between reading ability and auditory-visual matching. Combining her results with those of other investigators, Goodnow concluded that variations in auditory-visual matching skill among kindergarten and first- and second-grade children could not be accounted for by variations in any of the following factors: (1) auditory memory, (2) information capacity, (3) attention to the auditory series, (4) the appreciation that temporal intervals of different duration are represented by spatial intervals of different length, and (5) the spontaneous use of number "coding." Goodnow's subjects were well above average in intelligence and not specially selected with respect to reading ability, except in the experiment which examined variable (4) where they were divided into two groups, one containing normal readers and the other backward readers. Four out of five backward readers in grade 1 knew rule (4) but nevertheless had difficulty in making auditory-visual matches.

Kahn and Birch examined the relationship between reading ability, IQ,

and auditory-visual matching in boys from grades 2 through 6, the subjects again being selected without regard to reading ability. They also studied the influence on auditory-visual matching of factors similar to those considered by Goodnow, reaching much the same conclusion. The latter author believes that the major difficulty in the matching task is one of scanning in the correct order or of going back and forth between the two series to compare them.

In considering the concept of spatial order, it is necessary to make a distinction analogous to the one made earlier between form and shape. The *internal order* of a series is determined by defining for each element the two nearest neighbors (or nearest neighbor, if the element in question is at one end). The fundamental concept involved here, as in the case of form, is a topological one, namely, that of proximity (Piaget and Inhelder, 1956). The *egocentric order* refers to the spatial relationship between the observer and a series ordered in the above sense (i.e., internally). Restricting attention to the linear series, there is, in theory, an infinite number of egocentric directions which it could assume (but only a finite number could be detected) and for each direction a choice of two polarities. In practice, two directions, the vertical and horizontal, have been adopted by most cultures in the development of graphic systems. Whatever the specification of any particular system, an individual's apprehension of the convention underlying the order of text presupposes that he possesses a perceptual frame of reference. That such a reference frame subserves both the perception of orientation and the perception of (*egocentric*) order may be more comprehensible if it is appreciated that the identification of the upper-left symbol as the starting point of a scan is analogous to identifying the letter *b* by virtue of the relation of its discontinuity to the second (upper-left) quadrant. It should be emphasized that the perceptual frame of reference is necessary only to orient a series, not to determine its internal order, although it could presumably facilitate the latter process and may take over both functions in the mature reader.

A particularly germane study in the present context is one in which Huttenlocher (1967) has shown experimentally that there are parallels in children's ability to order and orient objects, and she concluded that this reflected a common developmental process subserving both tasks. Huttenlocher drew attention to Inhelder and Piaget's (1968) work (see also Piaget and Inhelder, 1956) in which they showed that during the early stages of development children performed better on a spatial ordering task involving a horizontal series if they made their copy directly below the model rather than in line with it. Huttenlocher was interested in the variable of direction as well as that of relative position, and in her first experiment she showed that a vertical series of colored blocks was easier for 4-year-old children to copy than a horizontal series, when the copy was made alongside the model. Now, at 4

years of age children have not gone beyond stage I of Piaget and Inhelder's sequence concerning axes of reference and would be expected to be relying on their ability to combine and coordinate proximity relations in order to construct these series. However, it appears that 4-year-olds are not entirely free of the influence of the Cartesian frame of reference because the results reflect the interaxis inhomogeneity of the frame referred to earlier. This inhomogeneity, in which the child's internal representation of left-right polarity is less firmly established than that of up-down polarity, is not surprising since at 4 years of age he has been chiefly exposed to a bilaterally symmetrical world. If the child were simply combining and coordinating proximity relations, the results for the horizontal orientation would not be expected to differ appreciably from those for the vertical.

In Huttenlocher's experiment, the apparatus constrained the child's actions in such a way that the series were constructed in a predetermined direction and polarity (from bottom to top, or from left to right), although this did not preclude the possibility of a reversed sequence. Thus it would be of no consequence that the subjects at this age could not construe the series in terms of a Cartesian frame because, provided they made their copies alongside and sufficiently close to the model, it would be sufficient for them to combine and coordinate proximity relations within and between the two series. But if the separation between model and copy is increased, or the copy is moved to an in-line position, then in transferring his attention from one to the other it would be necessary for the child to retain some internal representation of polarity. Note that since the direction of construction is subject to constraint, all that is required in this situation is an inchoate reference corresponding to a stage of development which is characterized by projective notions (of which left and right are examples). The fully elaborated Cartesian frame (a Euclidean concept in Piaget's terminology) is not necessary. Evidently, from the pattern of results, Huttenlocher's subjects were in the early stages of using projective notions: that they were compelled to use them in this experiment is not surprising since the separation of model and copy was a matter of 10 inches.

In the section on "The perception of Figure Orientation," not much was said about the relation between projective notions such as left, right, up, and down and Euclidean ones such as vertical and horizontal and the way they are integrated developmentally to form the fully specified concept of a Cartesian frame. Now that parallels have been drawn between the form of a figure and the internal order of a series (topological concepts) and also between shape and egocentric order (projective or Euclidean concept.), it is possible to make this relation a little more explicit. As Piaget's experiments have revealed, the child acquires projective notions before Euclidean ones. Consequently, if he is

at the former stage he should be able to accomplish those tasks which require an internal representation of polarity but do not require him to construe direction. The 4-year-olds required to copy the series in Huttenlocher's experiment were in the early stages of this phase. So are those children who can simultaneously discriminate mirror image shapes (e.g., *b*, *d*) but are not yet able to recognize or identify them. A child who failed on the mirror image task yet discriminated the letters *b* and *h* when presented simultaneously would have acquired topological concepts but not projective ones. Of course, compared to simultaneous discrimination, identification is a more complex task requiring discrimination and learning of the responses and also association between sound and symbol. But it appears that the developmental lag between the simultaneous discrimination of transformable letters and their identification, a period of at least 2 years, cannot be entirely attributed to immaturities in these other areas. For one thing, the average 8- or 9-year-old reader has mastered the identification of most letters but may still be having difficulty with reversible and invertible ones. As has already been predicated, the child must acquire the concept of direction as well as that of polarity before shape identification is possible. The interpretation offered in this paragraph is somewhat speculative, and further research is required to elucidate the relation between performance on the various tasks referred to and Piagetian stage of development.

The above account of the child's representation of order owes much to Piaget and Inhelder's formulation of the subject but departs from their analysis in one respect. They maintain that the concept of order is not the result of a process of abstraction from the complex of perceptual images but derives from actions performed on the object and their internalization in the child's representational space. Whether or not this is true in the case of topological concepts, it is difficult to see how, within the confines of this theory, it would be possible to account for the inhomogeneity of projective space.

Returning to Huttenlocher's work, in a second experiment she examined the effects of two variables on children's ability to reproduce the orientation of a bilaterally symmetrical figure (a "horseshoe"). The variables concerned were the relative position of sample and copy (above and below, or to left and to right) and the direction (Huttenlocher uses the term "plane") of the sample's axis of symmetry (horizontal or vertical). When the axis of symmetry was vertical, and the copy was placed to the right, there were no errors at all. When the axis of symmetry was horizontal, and the copies were placed below, there were still very few errors. However, if with the axis of symmetry horizontal the copy was placed to the right, or with the axis of symmetry vertical it was placed below, then the number of errors increased considerably,

with the usual interaxis inhomogeneity again being exhibited. These are effects comparable to those which occurred in Inhelder and Piaget's (1958) experiment and Huttenlocher's first experiment concerning order. The effect related to direction of axis of symmetry again reflects the inhomogeneity of the polar properties of the projective structure. The effect related to relative position reflects the fact that this structure was in any case only weakly established and the child's internal representation was still strongly influenced by topological concepts. While Huttenlocher's results provide trenchant evidence that the same structure underlies the perception of orientation and the perception of order in 4-year-olds, it does not necessarily follow that the same holds true at later stages of development. Confirmation of this prediction depends on further experimental studies.

In the section on "The Perception of Figure Orientation," it was argued that the difficulties which dyslexics have in perceiving a word as a gestalt could not be attributed to a defect in shape recognition or a gross defect in form recognition, but rather the limited capacity of form memory, at least as far as graphic material is concerned. Now, it is possible that this deficiency is a consequence of the child's inability to perceive order correctly. Gibson *et al.* (1963a) found that during the process of learning to read the child responds to progressively larger clusters of graphemes. Whether or not the recognition of those graphemes lying within the span of one fixation depends on an internal scanning process, the assembly or blending of these single-span clusters into larger clusters or words does depend on a sequence of fixations which is generated according to certain rules. The psychological and physiological basis for this overt scanning process was discussed at the beginning of the section. Thus whatever the size of cluster that is being handled at a particular stage of development, if the child lacks the correct scanning strategy the process whereby larger clusters are assembled would be subject to many errors. As a result, the child's acquisition of the rules governing the formation of "spelling patterns" is impeded (Gibson, 1965).

Visual Balance

In the course of their observations of dyslexics, diagnosticians often encounter impaired balance performance, and this assessment has been corroborated in recent studies by Cooke (1969) and Fox (1968). Cooke's study concerned a number of cognitive abilities including reading and employed tests of static and dynamic balance. His subjects were boys and girls between the ages of 8.5 and 12.9 years. Total balance performance was significantly correlated with reading ability in boys, but not in girls, the correlation being higher for the 8.5- to 9.9-year-old boys than for the remainder. Cooke's

finding is consistent with the observation that, in a group of dyslexics, boys outnumber girls, the ratio being of the order of 6:1.

Using 14 balance tests representative of static, dynamic, and rotational balance, Fox found that there is a relationship between balance performance and reading skills in second- and third-grade children.

There are four sensory systems which can be used to preserve postural stability: the vestibular apparatus, proprioception, vision, and touch. The interaction of these systems is probably very complex, but it is possible to come to some general conclusions (Howard and Templeton, 1966).

Normal standing posture is probably maintained primarily through proprioceptive control of the bilateral balance of muscle tonus. The vestibular system plays a relatively minor role in the maintenance of this condition but assumes relatively greater importance in situations involving higher accelerations. When standing, a person's body is never at rest but sways constantly from side to side. According to Edwards (1946), the amount of sway is about 50% less with eyes open than with eyes closed. Witkin and Wapner (1950) and Wapner and Witkin (1950) used an ataxiometer and a stabilometer to investigate subjects' postural steadiness under four different visual conditions: (1) room lights on, (2) room lights off, leaving in view a cube with its edges aligned with the vertical and horizontal of space, (3) nothing in view, and (4) an unstable rocking cube in view. They found that steadiness decreased progressively from condition (1) to condition (4). Thus vision is important for normal standing posture but is not necessary since blind people have no trouble maintaining steady posture (Edwards, 1946). However, in special situations, the visual reference can assume crucial importance: more than one pilot has found himself upside down in bad weather.

The principle involved in the visual balance mechanism (Fig. 3) is one that is common to all body orientation systems. The situation is illustrated in

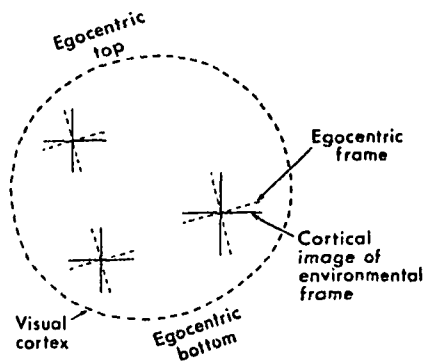


Fig. 3. The visual balance mechanism.

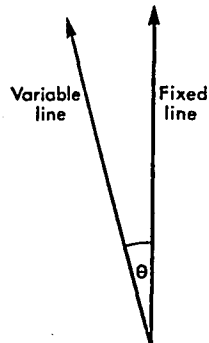


Fig. 4. The specification of body orientation.

Fig. 4. The fixed line represents the direction with respect to which the orientation of the body is to be maintained; the variable line, inclined to the fixed line at some angle θ , shows the instantaneous direction in which the body lies. It is also necessary to attach polarities to the two lines, bearing in mind that it is conventional for θ to be zero in the rest position of the body. For example, if the fixed arrow represents the vertical of space, and its head signifies the upward direction, then the head of the variable arrow represents the top of the body. On the other hand, if the head of the fixed arrow represents the downward direction, then the head of the variable one signifies the feet. Which is appropriate will depend on whether, for example, the subject has his feet on the ground or is hanging from a beam. However, the latter situation is one of stable equilibrium. Now if the organism has some means of measuring the instantaneous value of θ , the neuromuscular system can generate a torque proportional to the magnitude of the angle, in order to restore the body to its rest or equilibrium position. The above situation is assumed to be one in which self-righting is an appropriate response; in other situations, the subject may only be interested in having an estimate of the magnitude of θ . Whatever is the case, the organism requires information about the direction of both the fixed and the variable lines, in order to compute the difference θ . Clearly, in the particular situation under consideration, the verticals and horizontals of the retinal-cortical image serve as fixed reference lines (i.e., fixed in space), while the egocentric reference frame is inclined to them according to the departure of the body from the vertical. Although the principle of the mechanism has been discussed in terms of the gravitational vertical, the horizontal of space can obviously serve the same function, as is indicated in Fig. 3.

The mechanism outlined above can only effect self-righting if there is a

component of the body sway within the frontal plane. In other words, it is necessary for there to be a component of θ , the angle between fixed and variable lines, lying within the frontal plane. If these lines lie in a plane which is perpendicular to the frontal plane, it means that swaying is occurring in the anterior-posterior direction. The only visual consequence of such swaying is the looming and receding of objects in the field of view and, in addition, assuming the eyes are stationary in the head, movement of objects back and forth along a vertical meridian of the field. It is not clear what constitutes the fixed reference in this situation—possibly a memory trace of an object's retinal-cortical image size or retinal-cortical image location along the vertical axis (Rock, 1966). If so, it would be a much less stable reference than the egocentric frame, which could partly account for the finding that anterior-posterior swaying is of greater magnitude than lateral swaying.

In summary, it has been shown that the visual balance system relies for its operation on the egocentric Cartesian frame of reference. This suggests that dyslexics' poor balance performance stems from the lack of such a frame, although, in the absence of experimental confirmation, it would be premature to rule out alternative etiologies.

The Acquisition of Nonspatial Ordering Relations

The fifth aspect of psychological function which appears to be dependent on the Cartesian frame of reference is the child's acquisition of nonspatial ordering relations, including temporal relations and tenses. Although no systematic study has apparently yet been made, diagnosticians frequently encounter dyslexics who have difficulty differentiating the members of an antonymous pair of adjectives or who are unable to enumerate the months of the year correctly (Bender, 1958; Critchley, 1970; Laubenthal, 1936; Rabinovitch, 1962; Saunders, 1962). The purpose of the rather long review which follows is to reconcile two viewpoints concerning the structure of relational terms at the semantic level. The result of this examination, when viewed in conjunction with the preceding analysis concerning perceptual components of the symptom complex, appears to afford some justification for the general view of linguistics such as Chomsky and Bierwisch that semantic structures reflect perceptual and cognitive structures which are ontogenetically and phylogenetically prior.

At the time he was carrying out his experiments on the child's conception of left and right, Piaget (1928) noticed that the logical structure of certain of the tests (those corresponding to the development of stage III) was similar to the logical structure of the following syllogism: "Edith is fairer (or has fairer hair) than Suzanne; Edith is darker than Lili; who is the darkest,

Edith, Suzanne, or Lili?" Later, Inhelder and Piaget (1958) contrasted the solution of the same syllogism with a task which involves arranging small strips of wood in a series according to length. They noted that the former task could not be solved until 11-12 years, while the latter can be done at 7-8 years, even though they both conform to the same logical structure, and the concrete serial ordering of shades should be no more difficult than setting lengths in series. Inhelder and Piaget could not account for the age difference here, because they had found that children could reason correctly about simple propositions as early as the 7-8 year level, provided that the propositions corresponded to sufficiently concrete representations. They believed that some factor was at work which enabled the child to translate the data into representational imagery and proposed (1964) that spatial representations subserve nonspatial orderings in thinking.

DeSoto *et al.* (1965) have put Inhelder and Piaget's idea on a much firmer footing. In the first part of their investigation, they evaluated subjects' performance on the solution of syllogistic forms involving the relation *better-worse*. The main finding was that two paralogical principles would account for the relative difficulty of the various premise combinations. The first principle is that orderings are learned better in one direction than the other: the second is that orderings are end-anchored. How does the first rule apply to the *better-worse* relation, for example? What it means is that an evaluative ordering is more readily learned or represented internally if it goes from better to worse rather than from worse to better. This rule applies not only within a premise but also between the two premises as well. In other words, the syllogism is handled more easily if the elements of the first premise taken together are better than the elements of the second premise taken together.

The second principle, end-anchoring, refers to the tendency for terms at the end of a series of elements to be used as reference points. This predilection results in end items being judged more consistently, or memorized more easily, than other elements. DeSoto *et al.* hypothesized that in view of this phenomenon it would be easier for the subject if the first element given in a premise were an end element in the ordering, the best or the worst, so that the premise goes from the end to the middle rather than the other way around.

DeSoto *et al.* found that the two principles outlined above accounted for the relative difficulty of the various premise combinations used in their experiment. When the subjects were asked how they had solved the syllogisms, most of them indicated that they had used some kind of mental imagery involving the names of the elements (men's first names) arranged along a vertical axis, with the best man at the top and the worst at the bottom.

However, these reports do not indicate that the imagery is other than an incidental concomitant of the cognitive process. In the next two experiments, DeSoto *et al.* attempted to determine if there were any significance in the mental imagery. The first was designed to see how people overtly ascribed spatial directions to the relations *better* and *worse* and also a further pair, *lighter hair* and *darker hair*, chosen because they had no obvious relation with spatial direction.

Without going into the experimental method and results, the findings confirmed the subjects' introspective remarks, namely, that the vertical direction is the preferred one for representing the *better-worse* relation, and furthermore that *better* is fairly consistently ascribed to the top-bottom direction and *worse* to the bottom-top direction. But in the case of the hair-color relation, no one axis seems to be used more than the other. A further contrast is that the top-bottom direction is favored for both relations if they are assigned to the vertical axis, while the left-right direction is favored for both on the horizontal axis.

By itself, the foregoing result only demonstrates the possibility of overtly attributing spatial directions to nonspatial ordering relations; it does not mean that these images play a significant part in reasoning about such relations. However, the distinctive ways in which the system of axes was used for the two relations in the second experiment make it possible to make differential predictions about the relative difficulty of syllogisms involving them. In order to test their predictions, DeSoto *et al.* evaluated the subjects' performance on syllogisms involving the following relations: *better-worse*, *lighter-darker*, *above-below*, and *left-right*. Since their predictions were confirmed (with one exception not connected with the relative difficulty within premise combinations), DeSoto *et al.* concluded that spatial imagery is a significant process underlying people's reasoning.

Now, the investigation carried out by DeSoto *et al.* treats a more complex problem than is of immediate interest in this paper. The question which arises in the present context is whether spatial representation is necessary in order for the two relations of a kind to be uniquely distinguished, that is, put in a unique one-to-one relation to their referential circumstances. Or is the spatial model only necessary when it comes to solving syllogisms?

At one point DeSoto *et al.*, referring to their subjects, state: "Our hypothesis is that worseward is downward in their thinking" (p. 518). Moreover, betterward is upward. On the other hand, both *lighter* and *darker* may be downward but rarely upward. Thus the example of *lighter-darker* tends to invalidate the idea that the signifiers of the difference between two relations of a kind are, in general, upward and downward (or leftward and

rightward) spatial images—unless, of course, there are two or more classes of relations only one of which relies on spatial imagery for its signification. This conjecture seems reasonable, since in making the distinction between *lighter* and *darker* the subject can invoke visual imagery relating to luminance. On the other hand, there is no perceptual attribute to which the subject can refer directly to represent the difference between *better* and *worse*. Thus it appears that an arbitrary signifier is required in order to make the distinction between *better* and *worse*. While it is debatable whether spatial imagery is the only candidate capable of fulfilling this role, the fact that subjects apparently did not report using any other type of imagery suggests that spatial imagery may have an exclusive function in semantic processes.

If the foregoing interpretation of spatial paralogic is correct, it would be necessary for the individual to develop an intrinsic visual frame of reference, from which he could derive the imagery to subserve the acquisition of certain ordering relations. Without a spatial representation of upward and downward (or leftward and rightward), there is, if this imaginal theory can be accepted, no basis for the distinction between two relations of a kind. The fact that betterward comes to be allied to the upward direction is a matter of convention; however, this convention would have no significance for the individual if spatial imagery failed to develop.

It could be argued that spatial ordering relations are available in the image, at least in the case of the vertical axis, even if the trace giving rise to the image is not faithful to the egocentric orientation of the corresponding stimulus, in the same way that *up* and *down* are given by virtue of relations within the here and now visual field. But, as was pointed out previously when discussing the reference for figure orientation, it is not suggested that a specific image serves this function, but rather a property which is abstracted from the trace complex. Obviously, the abstraction of this feature would depend on the members of the trace complex being faithful to the orientation of the corresponding stimuli.

In a subsequent paper, Handel *et al.* (1968) coined the term “consistent relation words” for relations such as *better* and *worse* and the term “inconsistent relation words” for relations such as *lighter* and *darker*. The consistency referred to is that of the association of the word concerned with a particular polarity of the (vertical or horizontal) axis. In their study, Handel *et al.* investigated other ordering relations to see if those with the same spatial representation showed the same order of premise-combination difficulty. For example, *father-son* is conventionally thought of as lying on a vertical axis, with *father* at the top, so that the difficulty of premise combinations involving this relationship should follow the same pattern as those involving *better-worse*. The other relations used in the experiment, besides *better-worse*

and *father-son*, were *more-less*, *earlier-later*, *cause-effect*, *faster-slower*, *farther-nearer*, and *lighter hair - darker hair*.

The results confirmed that relations having similar patterns of spatial assignment do indeed have similar patterns of premise-combination difficulty. What emerged further was that the relations could be divided into three groups which were distinguished on the basis of both spatial assignment intercorrelation and premise-combination intercorrelation. The first group comprised the relations *better-worse*, *father-son*, and *more-less*, all of which were found, in the majority of subjects, to go from top to bottom in the spatial assignment task. The second group, consisting of *earlier-later* and *cause-effect*, implicated three types of spatial assignment, namely, top-bottom, left-right, and inconsistent. The third group, consisting of *faster-slower*, *farther-nearer*, and *lighter hair - darker hair*, was distinguished by the absence of any consistent spatial assignment. The inconsistency of *lighter-darker* was known from the earlier investigation carried out by DeSoto *et al.* Furthermore, *faster-slower* and *farther-nearer* seem to be distinguished from relations in the other two groups by virtue of the same kind of distinction postulated in the case of *lighter-darker*. That is, the "axes" along which these three relations lie, namely, velocity, radial distance from egocenter, and luminance, are all parameters to which the subject can refer directly in visual imagery. The remainder of the relations are not characterized by perceptual attributes.

Of special interest, perhaps, is the relation *earlier-later* because it implicates the dimension of time. Handel *et al.* found that over 70% of their subjects used a consistent spatial assignment for this relation. It seems reasonable to suppose, therefore, that subjects' appreciation of other temporal concepts such as tenses or days of the week also depends on spatial imagery. Again, if a child is learning to identify the letters of the alphabet he not only has to discriminate the stimuli, he also has to learn the responses. Now, the letters of the alphabet are by convention ordered in a particular way. If learning the alphabet (that is, the oral labels) is facilitated by the ordering convention, it follows that the kind of structure formulated by DeSoto *et al.* would play an important part. Some dyslexics have great difficulty in grasping the order of letters in the alphabet. Thus when looking up a name in a directory, they may start from one end and go through until they find the letter which matches the beginning letter of the given name. In doing so, they are reducing the task of identifying the spatial position of a grapheme to the simpler one of discrimination.

Clark (1969a) has questioned the theory proposed by DeSoto *et al.* on the grounds that the principles of preferred direction and end-anchoring cannot account for the relative difficulty of syllogisms containing the negative equative, rather than the positive comparative, form of a relation. He has

proposed three alternative principles which operate at the level of deep structure and which are claimed to succeed where spatial paralogic fails. The principles formulated by Clark are (1) the principle of the primacy of functional relations, (2) the principle of lexical marking, and (3) the principle of congruence. The first principle asserts that the subject analyzes premises at the level of the base strings which specify the underlying functional relations.

The principle of lexical marking is best understood in terms of an example. The antonyms *good* and *bad* underlying the relations *better* and *worse* are not symmetrical. While *good* can be understood in either a nominal or a contrastive sense, *bad* can only be understood in a contrastive sense. Accordingly, *good* is said to be an "unmarked" adjective and *bad* a "marked" one. Furthermore, there is some evidence that the nominal sense of an adjective is easier to store and retrieve than its contrastive sense. Applying this finding to comparative propositions, Clark argued that the *good* underlying the relation *better* would usually be understood in its simpler nominal sense. Of course, the *bad* underlying *worse* can only be understood in its contrastive sense. Consequently, the relations *better* and *isn't as good as* (which have the same base strings) should be more easily handled than the relations *worse* and *isn't as bad as*.

As applied to linear syllogisms, the principle of congruence asserts that the solution will be more easily obtained if the base string underlying the question is similar to the base string in the premise which contains the solution element.

Like DeSoto *et al.*, Clark evaluated his subjects' performance on linear syllogisms involving the relation *better-worse*. Furthermore, he used both the negative equative and positive comparative forms of this relation in compiling the syllogisms. As was expected, the results obtained in the case of the positive comparative syllogistic forms were in accord with both spatial paralogic and deep structure theory. However, there were two exceptions, one in the case of each theory. First of all, the prediction from spatial paralogic, fully confirmed by DeSoto *et al.*, that the preferred direction between premises is *better-worse* was supported in Clark's experiment in only half of the "problem types." Second, while none of the deep structure principles predicts a difference in solution time if the order of premises within a syllogism is reversed, Clark found that there was a significant difference when the two premises were homogeneous. In order to account for this phenomenon, he invoked an ancillary principle.

According to Clark, the predictions from deep structure theory concerning the negative equative syllogistic forms are just the reverse of those from spatial paralogic. He found that the former predictions were confirmed and considers that "The failure of spatial paralogic comes, apparently, from its

assumption that Ss work directly from the linear encoding of terms in surface structure, disregarding deep structure *per se* completely" (p. 400). This may have been the assumption made by DeSoto *et al.* in the case of positive comparative forms, but it does not follow that literally the same paralogical principles apply to the negative equative forms. In fact, there is a third principle implicit in the formulation put forward by DeSoto *et al.*, namely, that the spatial model applies to the positive comparative form of a relation. If the negative is removed from the negative equative form, but with the base string preserved (e.g., *A not as bad as B* transforms to *B worse than A*), and the paralogical principles are applied to the resulting positive comparative form, then Clark's data for the negative equative syllogisms are explained by both theories, again with the exceptions noted above. Furthermore, the fact that the solution times for syllogisms containing the negative equative form are significantly greater than those for the positive comparative syllogisms may be interpreted, as Clark recognizes, as being due to the processing time involved in removing the negative. However, if the subject removes the negative before applying the spatial model, there is no guarantee that the base strings are preserved. On the contrary, given people's preference for the better-to-worse direction, it might be expected that more base strings containing *bad* would be converted into base strings containing *good* than the other way round. This would result in the difference between solution times for Clark's problem types I' and II' being smaller than the difference between the times for types I and II. In Clark's experiment, this inequality was insignificant, which suggests that the base strings are preserved, although this simple interpretation is not the only one possible.

Clark (1969a) states that "The only firm conclusion we can draw at this time is that it has not been demonstrated that the use of spatial imagery differentially affects the solution of three-term series problems" (p. 402). It is true that DeSoto *et al.* did not directly compare a group of subjects who claimed to use spatial imagery with one who did not, but they did make differential predictions about the relative difficulty of syllogisms containing consistent and inconsistent relation words, and their predictions were confirmed. Furthermore, their finding that left-right syllogisms are generally more difficult than up-down syllogisms, not explained by deep structure theory, suggests that their group of subjects contained a proportion who relied on spatial imagery. On the other hand, Clark's (1969a,b) investigations have been concerned with only one type of relation, namely, the unmarked-marked pair. Nevertheless, when deep structure theory is used to interpret the findings of other investigators (DeSoto *et al.*, 1965; Handel *et al.*, 1968; Hunter, 1957; Huttenlocher, 1968), and attention is confined to the positive comparative form, the only relation which does not conform to the predictions made

about it is the unmarked-unmarked pair *earlier-later*. Against this may be set Clark's finding that deep structure theory successfully predicts the relative difficulty of positive comparative syllogisms containing the relation *deeper-shallower*, whereas spatial paralogic, in this instance, fails. The foregoing considerations lead to the conclusion that the status of deep structure theory and that of spatial paralogic are much more evenly matched than Clark maintains.

Jones (1970) found that there is a relation between the different classes of words in the two theories. Marked-unmarked pairs appear to correspond to consistent relation words and marked pairs to inconsistent relation words. She also "confirmed" Clark's assumption that in the case of consistent relation words the majority of subjects use the same spatial assignment for the negative equative form as the positive comparative form. However, this assumption is neither here nor there, since it is consistent with the ancillary principle that subjects transform the negative equative form into the positive comparative form. The latter principle receives some support in Jones' study: 13 out of 20 subjects stated that they transformed the negative equative form before making the spatial assignment.

In the second part of her study, Jones showed that both theories explain the relative difficulty of positive comparative syllogisms involving the relations *heavier-lighter*, *darker-lighter*, *thicker-thinner*, and *fatter-thinner*. On the other hand, the results for the negative equative forms *not as good as - not as bad as*, *not as happy as - not as sad as*, and *not as happy as - not as unhappy as* were said to favor deep structure theory. But if, as before, the findings are interpreted in the light of the ancillary principle, the only aspect of spatial paralogic which is in question is the assertion that the preferred direction between premises is top to bottom (or unmarked-marked).

If there is any justification for concluding that both the spatial paralogic and deep structure models are "correct," the question then arises as to whether the corresponding psychological mechanisms are independent or not. At the beginning of this section, it was hinted that the deep structure mechanism may be derived in some way from the spatial imagery. This imagery is not apparent during conversation, but it is resurrected in order to facilitate cognitive tasks such as the solution of syllogisms. One consequence of this theory is that while some subjects might rely solely on spatial imagery in solving linear syllogisms, one would not expect to find an individual who is able to solve them verbally but is incapable of invoking the corresponding imagery. This prediction would be difficult to verify in the normal population, but it could be put to the test by evaluating the extent of ordering defects in dyslexics, who, if the general hypothesis is correct, should have no perceptual basis for the kind of imagery required. If the linguistic and imaginal

mechanisms are independent, there should be a significant proportion of dyslexics who have no difficulty with syllogisms or two-term series problems in spite of their lack of an egocentric frame of reference. But if dyslexics are uniformly characterized by their poor performance on this kind of task, then it would suggest that one mechanism is just a reflection of the other. In the absence of such evidence, the interpretation offered here must naturally be viewed as a very tentative one, the force of the argument deriving largely from the resulting internal consistency of the symptom complex. But it may be significant that while Clark (1969a) comes out in favor of the linguistic model, the nomenclature (Bierwisch, 1967) which he uses for lexical marking, [\pm polar], is directly derived from spatial imagery.

The suggestion made above, namely, that the semantic differentiation of members of a comparative pair depends on the establishment of a perceptual structure which both ontogenetically and phylogenetically precedes it, needs to be examined in the light of what is known about the child's acquisition of the comparative. Given the present state of knowledge, it is not possible to carry out a comprehensive analysis, but a start may be made with the comparative *more-less*, a relation which has been examined in a number of studies (Clark, 1970; Donaldson and Balfour, 1968; Donaldson and Wales, 1970; Wales and Campbell, 1970).

The word *more* makes a very early appearance in the child's speech—usually well before 2 years of age. At this stage, it is used and understood in the nominal sense, i.e., in the sense of "a quantity of" or "some." Later, the child comes to understand *more* in a contrastive sense but at the same time interprets *less* as being synonymous with it. It is not clear when this stage begins, but it apparently applies from 3½ to 4½ years (Donaldson and Balfour, 1968). Around 5 years of age, *less* becomes differentiated from *more*, but in a constricted sense. It is constricted insofar as the child can only relate two quantities at a time; i.e., he is not able to recognize that B can at the same time be more than A and less than C. No data appear to be available for the relation *more-less*, but Piaget found that the solution of a linear syllogism involving the relation *fuirer-darker* was not possible until 11-12 years of age. Clearly, this kind of problem calls for a fully elaborated concept of relation.

Now, it is possible to discern a connection between the perceptual frame of reference and the semantic structure of a comparative pair at two points during their ontogenesis. First, the differentiation of *more* from *less* (at least in the constricted sense) may be predicted on the acquisition of the perceptual, projective frame of reference and in particular the up-down component thereof. If the ability to simultaneously discriminate up-down mirror images signifies the establishment of the projective frame, then the age at which it develops is somewhere between 3 and 5 years (Davidson, 1935;

Huttenlocher, 1967). This conforms very roughly with the age at which the marked and unmarked adjectives are differentiated. Second, if the ability to solve syllogisms constitutes evidence for the child's complete apprehension of the comparative, then the age at which this task is first achieved (11-12 years according to Inhelder and Piaget, 1958) is consistent with the assertion that the perceptual, Cartesian frame is a necessary precursor. The latter structure is not fully developed until at least 9-10 years (Piaget and Inhelder, 1956). The additional component of direction may become essential at this stage because there is ambiguity about the middle member of three spatially distributed points unless they all lie on a straight line. Now, the concept of a straight line may be determined in either projective or Euclidean terms. However, it is hard to see how the "method of sighting" (Piaget and Inhelder, 1956), which defines the concept in projective terms, could operate in the absence of specific perceptual props and actions directed at the objects concerned. It seems more likely that the image of a straight line is generated by a series of direction-preserving displacements, which presupposes an internal frame of reference whatever the particular direction adopted. Of course, the most convenient directions for this purpose are the directional references (vertical or horizontal) themselves. If the foregoing interpretation is correct, it would substantiate the general view which has been put forward by Bierwisch (1970): he envisages that "all semantic structures might finally be reduced to components representing the basic dispositions of the cognitive and perceptual structures of the human organism (p. 181).

The Characteristic Intellectual Profile of Retarded Readers

It is reasonable to suppose that the perceptual deficit discussed in this paper, with its consequences for both form recognition and the acquisition of nonspatial ordering relations, would be reflected in a test of intelligence such as the WISC. Several authors who have investigated the performance of retarded readers on such tests have found a characteristic pattern of results for their subjects. Belmont and Birch (1966) summarized various features of 13 investigations which employed the WISC. In every case but two, in which the findings were not given, the mean verbal IQ score was less than the mean performance IQ score for the group. Very often, groups of normal readers of comparable age exhibit the opposite pattern. Unfortunately, every one of the studies referred to above was faulted by Belmont and Birch on the grounds that it suffered from one or more methodological weaknesses. Belmont and Birch attempted to correct these deficiencies, and it is the findings from their study which will be related to the present analysis.

In 1962, Belmont and Birch carried out an epidemiological study of

reading ability in all children between the ages of 7 and 11 in the city of Aberdeen. From this population was selected, for the purposes of the 1966 study, a sample of 150 boys in the 9-10 year age group who were backward readers, their scores on three or more of the four reading tests used placing them in the bottom 10% of the population. One hundred and fifty boys whose reading ability did not conform to this criterion were matched to the backward readers for birthdate and school class. Of these, 50 were selected to form the normal comparison group. One-third of the retarded readers were at least 2 years behind the average performance of the normal group, and about 97% were more than 1 year behind. All 12 subtests of the WISC were administered to both groups. The analysis of the two groups' performance was carried out in four stages, and in each of these the range of intellectual performance and reading ability which was subjected to analysis, in the retarded readers' group, was progressively restricted. The findings for the fourth stage of analysis were similar to those of the previous three stages except that the differences already found between the two groups were magnified. In the fourth stage, a subgroup of the retarded readers was chosen whose performance was below the tenth percentile on all four reading tests. The purpose of this restriction was to emphasize any characteristic divergences of the retarded readers' scores from those of the comparison group. It was intended to match, for full scale IQ, each member of the subgroup of severely disabled readers with a member of the comparison group. But of 28 boys in this subgroup only 22 could be matched within 2 IQ points with members of the comparison group. As far as reading level was concerned, the group of 22 poorest readers was on average 1.8 years behind the matched group of normal readers. In view of its members' reading level and IQ performance, the fourth group is more likely than any other selected for analysis in the study to have contained a large proportion of individuals who would have been diagnosed as dyslexic.

When the WISC data from the group of retarded readers were analyzed, it was found that the mean performance IQ was significantly higher than the mean verbal IQ; the converse was true in the group of normal readers. Belmont and Birch also gave an analysis, by subtest score, of WISC performance for the two groups. On all the verbal scale subtests except Comprehension, the normal readers scored higher. On the other hand, the retarded readers gained higher average scores on all subtests of the performance scale. The differences in performance were significant in the case of the Vocabulary, Arithmetic, and Information subtests of the verbal scale and also in the case of the Object Assembly subtest of the performance scale. The differences between the subtest scores of the two groups were also examined using a graphic method. This analysis revealed especially large divergences in the case

of the Vocabulary subtest, on which the retarded readers' score was very low, and in the case of the Object Assembly subtest, where their performance was relatively strong.

Looking at the above results, it might be argued that the low score on the verbal scale, especially on the Vocabulary subtest, is a predictable concomitant of reading retardation and that if the two groups are matched for full scale IQ, then the performance IQ of the retarded readers will, *ipso facto*, be relatively high. But this interpretation does not take into account all the relevant considerations. For one thing, the absolute value of the retarded readers' verbal scale score, namely, 94.8 ± 7.4 , would not, in general, be a concomitant of reading disability. Indeed, the general population contains a number of individuals of comparable age and with much lower (~ 20) verbal IQs whose reading age is, nevertheless, much closer to the average. Thus there is no *a priori* reason to suppose that retarded readers of average full scale IQ will score low on the verbal scale compared with the performance scale, and the opposite pattern would appear to be equally likely since the performance tests involve many instances of visual matching and identification. Nor are these two profiles the only ones possible: it could have transpired that there is a positive discrepancy in the case of tests drawn from both the verbal and performance groups. Furthermore, even when the full scale IQ scores of the two groups differ, as they do in the first three stages of Belmont and Birch's analysis, a similar pattern of divergence is obtained. For example, the initial analysis concerned 150 retarded readers and 50 normal readers, the mean full scale IQs of the two groups being 92.1 and 104.9, respectively. Belmont and Birch found that 60% of retarded readers were characterized by PIQ/VIQ greater than 1 and that 60% of the normal group were characterized by VIQ/PIQ greater than 1, a difference which is significant at the 0.01 level. It was also possible to employ the same graphic method that was used in the fourth stage of analysis since it is independent of the absolute values of the groups' full scale scores. In this instance, all but one (Block Designs) of the retarded readers' performance scores diverged positively, and all but one (Coding) of the verbal scores diverged negatively.

The characteristic divergence of the two subtests (Vocabulary and Object Assembly) singled out in the last but one paragraph may be interpreted in the light of the present analysis. However, it is not claimed that the explication of Belmont and Birch's findings is a rigorous one, particularly in the case of the Vocabulary subtest. Before proceeding, some considerations from the previous section will be recalled. It was suggested that the two members of a consistent relation pair are semantically differentiated by way of being assigned to opposite polarities of an axis of the Cartesian frame. For the purposes of normal usage, it is not necessary for inconsistent relation

words to be assigned to the frame because the attribute involved in the relation may be referred to directly in visual imagery. If dyslexics fail to develop an intrinsic frame of reference, there is no basis for them to distinguish certain elements of the vocabulary which rely on such a structure, and they may be expected to have difficulty in grasping consistent relation words. On the other hand, dyslexics' understanding of inconsistent relation words should not be affected, although it may not be possible to say the same about their performance on syllogisms involving this type of relation.

Now, if any consistent relation words occur in the Vocabulary subtest of the WISC, dyslexics' performance may be adversely affected. There are, in fact, two consistent relation words in this subtest: one is *imminent* (word 33) and the other is *dilatory* (word 38). While neither is a comparative adjective or adverb such as *earlier-later*, the notion of temporal polarity is certainly involved insofar as they both refer to the "direction" *later*. However, they are distinguished by the magnitude of the time interval concerned, as well as in other ways. This does not amount to an explanation of Belmont and Birch's findings because the age range of their children was such that very few of them would be acquainted with words beyond number 25 in the list. However, it is conceivable that these two consistent relation words represent the "tip of the iceberg," for, as Donaldson and Wales (1970) and Peirce (1933) have argued, lexical elements are largely composed of relational terms, the exceptions being certain words such as proper nouns and demonstratives. It is apparent that even in the case of nouns a relational component may be extracted from many word sets. For example, the relation *larger-smaller* is a component of the noun set: city, town, village, hamlet. An analysis of the Vocabulary subtest may reveal similar semantic components. Although it is not really known to what extent the verbal deficit results from the backwardness in reading, the latter is unlikely to be the sole factor since the deficit is qualitative as well as quantitative: Belmont and Birch found that while normal readers defined more nouns categorically than descriptively, the converse was true for retarded readers. Other investigators have found that compared with average readers of the same age, dyslexics are more familiar with nouns than with verbs or adjectives.

The Object Assembly subtest involves four puzzles of the jigsaw variety, except the joins between the pieces are straight edges. No more than seven pieces are involved in any of the puzzles. Before presenting the test to the subject, the examiner arranges the pieces according to a predetermined pattern which prescribes both their orientation and relative position. The orientation of each piece is not necessarily the same as it occurs in the completed puzzle. All four puzzles involve mono-oriented objects, and in two instances—those depicting a boy and a horse—the subject is told what the completed object is;

in the other two cases—a face and a car—he is not told. Now, it was suggested in an earlier section that form recognition in the normal child is dependent on the egocentric orientation of the figure, especially if the background is a homogeneous one. If the puzzle is lying on a table in its initial state, then the surface of the table provides such a background. As far as the recognition of any given piece is concerned, the layout of the other pieces surrounding it can hardly affect the situation one way or the other, provided their position and orientation are randomized. In postulating that form recognition in normal subjects is dependent on orientation, the implication is that it is easiest when the object is in its usual orientation and becomes more difficult the greater the departure from this position. There is some evidence for this phenomenon in the case of adult subjects (Gibson and Robinson, 1933; Yin, 1969), but it is not clear whether the same applies for children of the same age as those who took part in Belmont and Birch's experiment. Apparently the only investigations in which subjects in this particular age group were included are those of Brooks and Goldstein (1963) and Hunton (1955). The former study examined how difficult it was for subjects to identify inverted photographs of their classmates. Brooks and Goldstein found that identification was impeded by this transformation at every age between 3 and 14 years, the decrement being least in the case of 10-year-olds. Hunton's experiment was concerned with a somewhat different aspect of the stimulus configuration, namely, the relation between figures rather than the form of the figures themselves, although the recognition of such relationships would to some extent be dependent on form recognition *per se*. Now, if recognition of a mono-oriented object by normal 10-year-olds is more difficult when it is disoriented, it seems reasonable to suppose that the same holds true for the individual pieces of a puzzle depicting such an object. On the other hand, the orientation variable would be of less consequence for the child who lacks an egocentric frame of reference. The foregoing hypothesis could be tested by presenting a puzzle to groups of normal and retarded readers and systematically varying both the number of pieces which are rotated from the preferred position and the degree of rotation. In the light of the above analysis, the orientation variable should affect the retarded readers' performance time to a lesser extent than it does the normal readers' time. Further research is therefore needed before it can be concluded that the positive divergence of retarded readers' scores on the Object Assembly subtest is definitely due to the lack of an egocentric frame of reference.

It is possible that object orientation and its effect on form recognition are a factor in the Block Design subtest, but no detailed analysis is presented here. Other subtests of the verbal scale may also be dependent on the acquisition of a cognitive reference frame. This is perhaps most apparent in

the case of the Digit Span subtest, which requires subjects to order a series of items and assign them to a prescribed (temporal) polarity. While performance on the Digits Forward part of the subtest may be solely a function of auditory rote memory, this faculty may not be sufficient when it comes to the Digits Backwards trials. It may be necessary to assign the digits to a spatial axis before the reverse order can be generated. This interpretation is consistent with Schiffman's (1962) observation that the forward span of digits is greater than the reversed span.

CONCLUSIONS AND IMPLICATIONS FOR FURTHER RESEARCH

The existence of a symptom complex in a neurological disorder usually provokes speculation about a unitary etiology. In the past, it has been customary first to define such symptom complexes by assessing whether their incidence amounts to anything more than chance occurrence and then to try to analyze their cause. In the case of dyslexia, it has not been possible to adopt the same strategy, except in a gross way, because although several features are regularly associated with the disability, the number of combinations of such features appears to be almost as large as the dyslexic population. Again, the range and complexity of the associated phenomena are formidable, while the proportion of them selected—usually arbitrarily—for study in any given investigation has generally been small. Consequently, it has not been possible to reach agreement on the classification of subgroups.

In the present study, the usual procedure has been reversed: a symptom complex has been analyzed before its existence has been verified. Nevertheless, it would be surprising to find that the phenomena analyzed are not associated in the individual dyslexic since each has, by itself, been linked with severe reading disability. As for the implications for normal psychology, the existence of the disability means that the concept used to unify its description is more than a device which systematizes the phenomena in the mind of the investigator: it serves the same purpose, but in a functional rather than a formal way, in other individuals' brains as well.

Assuming that the existence of the symptom complex described here is verified, it would still remain to be shown that it is related to the individual's performance on the supplemented version of Piaget and Inhelder's sequence concerning axes of reference. So far, the only evidence for this hypothesis is circumstantial. According to Monroe (1932) and Schonell (1948), normal children continue making reversal errors up to the age of 9 years; Piaget and Inhelder found that stage IIIB of their sequence begins at about the same age. If this relation is more than circumstantial, then the diagnosis and remediation

of the disability could be approached in a much more systematic fashion. Piaget and Inhelder's developmental sequence could form the basis of a diagnostic tool with very much finer resolution than those presently obtaining. It should be possible to locate the child at one of the six stages making up the sequence (Piaget and Inhelder's stages I, IIA, IIB, IIIA, IIIB, or the supplementary stage based on Rock's experiment); remediation might then be designed in order to induce transfer from one stage to the next. But even with a systematic basis to work from, the chances of remediation succeeding cannot be counted very high because the disability is almost certainly of constitutional origin and in many cases is congenital.

As far as is known, Beilin *et al.* (1966) and Smedslund (1963) are the only investigators who have studied the effect of training on the child's acquisition of horizontality. In the latter study, the training schedule affected only those subjects who were already beginning to grasp the concept prior to training. Beilin *et al.* found that "perceptual confirmation" training was superior to "verbal instruction"; again, most of the subjects who attained the concept on post-test had been at stage IIIA on pretest, nor was there any significant transfer to jars of a different form from those used in training. In any case, the lessons learned from studies with normal subjects will not necessarily apply when it comes to designing remediation for a disability like dyslexia. Even though a certain amount of success is achieved at present using intensive teaching methods, it is debatable whether improvements in these methods will ever be sufficient to guarantee dyslexics' mastery of reading and writing. Thus while the approach to remediation outlined here is one which could be explored immediately, its potential usefulness is probably limited. It is more likely, in view of the constitutional origin of the disability, that effective remediation will ultimately depend on elucidating its nature at the genetic, biochemical, and physiological levels. If so, the psychological structure described in the present study may be useful in the search for neural correlates.

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